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TERRITORY OF NEW GUINEA.

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PROGRESS OF WORK ON SEXAVA SPP., THE COCO-NUT TREEHOPPER.

B. A. O'Connor, B.A., B.Sc.Agr., Assistant Entomologist.

A summary of the investigation into the bionomics and control of this pest up to the latter part of 1935 was published by the Entomologist, Mr. J. L. Froggatt, in Vol. 1, No. 1, of this journal. Since then, further work has been done, which is briefly outlined in this article.

The research station was transferred from New Hanover to Arawe Plantation, New Britain, at the end of April, 1935, the object being to establish the two egg-parasites, *Leefmansia bicolor* and *Dorinia leefmansi,* in that district. In early February, 1936, New Hanover was again visited, and a large number of eggs, parasitised by various species of wasps, was collected. These eggs were then taken per the M.V. *Poseidon* to Mokareng Plantation, Manus, the original site of the research station, and work has been in progress in this locality up to the present time.

Life-history and Habits.

Technique of Breeding.—Rearing of the treehoppers was carried out in a calico enclosure 6 feet by 6 feet by 6 feet. In the New Hanover structure there was a double roof, the two pieces of calico being separated by a space of a foot. This proved fairly satisfactory, but was too warm, the temperature frequently reaching 100 degrees Fahr. In Manus, a thatched roof was first constructed, about 11 feet high, and covering an area 12 feet by 12 feet. Under this the calico enclosure was built, portions of the roof and sides being made of fly-wire, to permit of adequate ventilation. The floor was of galvanized iron sheets, to prevent the females from laying indiscriminately in the soil, and a tray containing moist soil was provided for oviposition. This was frequently sieved during the egg-laying period, and the number of eggs counted. The enclosure had, of course, to be made proof against the entry of predators such as small lizards. Fresh food was provided daily, portion of a coco-nut frond moistened with water being suspended from a wire stretching from side to side of the roof. The insects could then be taken from the old frond and placed on the new, their numbers and stage of development being noted at the same time. In these calculations, mortality was found to be very heavy during the first nymphal stadium. Out of 155 newly-hatched nymphs which were used at Manus, 58 died before reaching the second instar. Of the remaining 97, 67 reached the adult stage. Probably there is a similar mortality in the field, as the first-instar nymphs seem particularly vulnerable to adverse conditions.

Information Obtained.—Results of rearing treehoppers in Manus show that the life-history here is very similar to that of the New Hanover species. The only species recorded from Manus is *Sexava novae-guineae,* whereas in New Hanover this species is present together with *S. nubila.* The characters which separate the two species are not known to the writer, but it seems probable that *S. nubila* is the dominant species in New Hanover, and that it was the species on which life-history studies were carried out in that locality. One definite difference in life-history was noted to exist between the Manus and New Hanover treehoppers. In the latter, the males have six and the females seven nymphal stages. The Manus species has seven nymphal instars in the female, but only one-third of the males have six instars, the remaining two-thirds having seven, as in the female. The two types of sixth-instar male can be distinguished by the development of wings and elytra, and have been called the macropterous (large-winged) and the micropterous (small-winged) types. The former corresponds to the normal New Hanover male, while the wing-development in the latter proceeds as in the female nymphs.

Copulation was not witnessed in New Hanover, though it was thought to take place between midnight and the following dawn. In Manus, it has been seen on several occasions, and takes place at about sundown. The males show sexual excitement by stridulating and depressing the abdomen convulsively. The actual act of copulation takes a very short time. The male ranges himself alongside the female, facing in the same direction. He then curves his abdomen under that of the female, brings his genitalia in contact with hers, and extrudes a whitish, gelatinous blob, which remains attached to the female for a period of from 12 to 24 hours. This blob of fluid is the spermatophore, a gelatinous envelope containing the seminal fluid. In New Hanover, females were known to have copulated during the first 24 hours of their adult life, but in Manus there were no indications that mating had taken place until ten days after the first female had reached the adult stage. Since then, copulation has taken place daily in the breeding enclosure, covering a period of nearly eight weeks. Out of the 30 females and 37 male adults which were reared from the time of hatching, there are now 20 female and 27 male survivors.

Oviposition began 33 days after the first female became adult, and during a period of a month 900 eggs have been laid, an average of 30 per adult female. When oviposition is completed, the average will possibly be between 40 and 50.

The eggs which have been incubated in the laboratory have hatched in from 49 to 59 days from the time of laying, with an average incubation period of 51 days. The numbers handled so far have been comparatively small, so that later results may give a somewhat different figure.

The immature or nymphal stages between egg and adult occupy much the same time as was the case with the New Hanover species. The seven nymphal stages of the female occupied a period of from 90 to 124 days, with an average of 100.9 days (New Hanover 100.6), while the male nymphal instars lasted for from 78 to 117 days, with an average of 92.4 (New Hanover 88.4). In New Hanover, the total time from egg to egg (i.e., one generation) was found to average just seven months, and it is apparent that the results obtained in Manus will be very similar. In the field, however, it is probable that the life-history in New Hanover occupies a period of about a month longer, as the average temperature there is about 2 to 3 degrees Fahr. lower than at Mokareng. The

breeding chamber in New Hanover was of a type which conduced to high temperatures, while that at Mokareng was very cool, so that the difference in field temperature was obscured. The incubation of eggs took place under comparable conditions in the two localities, and the average period of incubation was 61.8 days in New Hanover compared with 51 days in Manus.

Egg-parasites of Sexava spp.

When it was decided to move the research station from New Hanover to Arawe, arrangements were made to transfer three species of parasites to the new site, namely *Leefmansia bicolor, Dorinia leefmansi* and an Encyrtid common in New Hanover, both the latter having been shown to be primary parasites of Sexava eggs. *Dorinia* seemed in particular to have exercised definite control over the treehopper in New Hanover, being widely distributed and parasitising up to 72.5 per cent. of eggs collected in certain localities. (The figures for percentage of parasites were obtained by the dissection of many thousands of newly-collected eggs.) It was also hoped that the Mymarid parasite, which was second in effectiveness to *D. leefmansi,* might establish itself when it emerged from eggs collected in New Hanover, though it had been found that it would not breed satisfactorily under laboratory conditions. Unforeseen delays in transit caused the loss of all the Mymarids and most of the *D. leefmansi,* but *L. bicolor* and the other Encyrtid were successfully transferred. On the way to Arawe, a visit was made to Ablingi Plantation, which was very bady attacked by Sexava, and some thousands of eggs parasitised by *L. bicolor* were suspended in the affected areas. Many thousands of adult *L. bicolor* were also liberated there. It is not known whether or not the parasite has become established in this locality, as it has not since been visited.

Work was carried on for nine months at Arawe, during which time *L. bicolor* became established in several places, but *D. leefmansi* showed no signs of doing so. This was only to be expected, as very few of this parasite had arrived at Arawe, and it is at all times difficult to breed in the laboratory.

As *D. leefmansi* and the Mymarid were so well established at New Hanover, and seemed to have been effective in keeping Sexava attack down to a reasonable level, it was decided that an effort should be made to establish these parasites in Manus, where the depredations of the treehopper are at their worst. As both species, particularly the Mymarid, fail to breed well in the laboratory, the method used was to collect large numbers of eggs at New Hanover, where both parasites occur in very large numbers, and transfer them direct to Manus at the time when the research station was being shifted there from Arawe. It would, of course, have been desirable to have sent a number of shipments of eggs, but transport was not available for the execution of such a scheme.

A visit of about three weeks' duration was made to New Hanover, and a very large number (approximately 1,000,000) of heavily-parasitised eggs was collected, and transferred to Manus per the M.V. *Poseidon.* Numerous samples of these eggs showed a parasitism of 72 per cent. by *D. leefmansi,* and in many cases there were as many as 22 per cent. attacked by the Mymarid. The greater portion of the eggs was distributed throughout Mokareng Plantation, small containers of fly-wire being used to suspend the eggs from palms, and thousands of parasites were seen to emerge. However, there is as yet no evidence that they have established themselves in the field.

Investigations have been made to ascertain whether *L. bicolor,* which was established on Mokareng Plantation in 1934, is still present. So far, results have been disappointing, as none of the wasps have emerged from eggs collected in the field. Of course, this does not prove that the parasite is a failure, for it may be present in small numbers, and may possibly take a number of years to become acclimatized. On the other hand, it is evidently not going to deliver very quick results, so that, while breeding and distribution of *L. bicolor* will be continued, more attention is being paid to the question of control by artificial methods.

Artificial Control.

Experiments have been conducted at Mokareng into the killing effect of arsenate of lead sprays applied to the foliage of the coco-nut palms. A small palm was sprayed with mixtures of ½ oz. and 1 oz. of arsenate of lead powder to the gallon of water, and leaves were then fed to captive treehoppers. Control lots of insects were fed on unsprayed leaves. In every case there was 100 per cent. mortality within from three to five days among those fed on sprayed leaves, while the control lots showed only an insignificant number of deaths. It has not been possible to conduct field trials as yet, owing to the lack of a sufficiently powerful spraying machine. Consideration is being given to the purchase of a dusting machine, so that the arsenate of lead powder can be applied in the dry form. It is considered that this would be much quicker and simpler than spraying, owing to the mobility of the apparatus, and the elimination of the need for large quantities of water.

RÉSUMÉ OF THE ACTIVITIES OF THE DEPARTMENT OF AGRICULTURE.

FOR THE YEAR ENDED 30TH JUNE, 1936.

On 9th February, 1936, the Director returned from nearly twelve months' leave of absence, during which he attended the Imperial and International Botanical and Entomological Congresses in London, Amsterdam, and Madrid, respectively.

At these Congresses he had the opportunity of hearing many valuable papers and took part in some of the discussions, while personal contact with fellow workers from other fields was also of inestimable value in connexion with his work in New Guinea.

The rest of his leave was spent in study at agricultural research stations, departments of agriculture and estates in several tropical countries.

The violent fluctuations in the prices of copra and coco-nut oil have been succeeded by strong upward movements which have given a feeling of greater hopefulness and security to the coco-nut planters of the Territory, some of whom were beginning to fear the stability of our staple crop, and were interplanting their palms with cocoa.

Various abnormal causes have, no doubt, been partly responsible for the upward trend in prices, as e.g., droughts in America, resulting in a shortage of domestic fats and the vicissitudes of the European political situation and the prospects of war.

Whatever the cause, however, the natural consequence of increased copra prices was a larger output, and it is satisfactory to note that there was also a general improvement in the quality of the copra. Improved weather conditions after the drought, in some districts, have, no doubt, had some affect on the larger production, and the better quality of the copra is due to the system of copra inspection and inspection of driers by inspectors and instructors. The export of copra during the past year was 66,684 tons, as against 56,251 tons for the previous year.

The method of processing all town refuse from whatever source into innocuous compost was demonstrated to the Public Health Department, and is now put into general practice at the Sanitary Depot near Rabaul. The method was devised by Sir Albert Howard, C.I.E., Director of Indore Agricultural Research Station, and hence is known as the "Indore Process." When properly carried out, no flies are bred, while there is an absence of noxious odours, and the resulting compost has the appearance of any good garden soil.

Copra.

As already noted, the output of copra has greatly increased and the quality improved during the past year; the prospects for the industry are now much better than formerly.

Exports of copra during the year ended 30th June, 1936, amounted to 66.684 tons, valued at £761,309.

Desiccated Coco-nut.

Restriction of production of this product has been necessary owing to the fact that our market is confined to Australia and New Zealand. The quantity exported during the year amounted to 1,647 tons, valued at £65,880.

Coir Fibre.

A mill has been erected for the preparation of this product, but there were no exports during the year ended 30th June, 1936.

Coffee.

Although two plantations of this product are in a very satisfactory condition, and are commencing to yield, the exports for the year amounted to only 11 tons, valued at £880. The quality of the coffee is very good indeed, and is well received on the Australian market. There is a considerable local market for this article, and a few of the smaller planters dispose of their crops in this way. The Arabian coffee (the original stock imported from Blue Mountains, Jamaica) is doing very well, and is all sold locally at good prices.

Cocoa.

Greater interest than ever is being taken in the cultivation of this crop, for which the prospects seem very favorable. The quality of the bean is good, and apparently the prejudice in Australia against New Guinea cocoa is breaking down. The export for the year amounted to 127 tons, valued at £3,810, an increase of 32 tons over that of the preceding year.

Tobacco.

This crop is grown only for local consumption by natives who, so far, do not take very kindly to the locally-manufactured stick tobacco. Dry leaf is, however, acceptable to them, and is part of the ordinary issue in accordance with the Native Labour Ordinance.

Rice.

Results, at the demonstration plantation, and by native cultivation under officers of the Department of Agriculture, prove conclusively that good rice can be grown successfully here. Numerous experimental plantings have been made by mining companies on the mainland, and the yields per acre were quite satisfactory.

Some planters at Siassi Island have, to some extent, successfully encouraged the growing of rice by natives. It is produced under the condition that the natives grow the rice, while the rice is bought and milled in a small mill, by the planters concerned.

Kapok.

Only one planter has taken up the cultivation of this product seriously, and he is more than satisfied with his results, his crop all having been sold locally.

Derris.

Experimental plantings of this crop are being continued at the demonstration plantation, and a small lot was sent to London for valuation.

Peanuts.

A little more interest has been taken in the cultivation of this crop, as 35 tons, valued at £653, were exported to Australia—an increase of 10 tons over the preceding year. A considerable quantity is also consumed locally by the Chinese community.

Areas under Cultivation.

Owing to incomplete statistical returns, it is not possible to supply full details, but from inspectors' reports it is certain that there has been an increase in areas under coco-nuts, and there is a steady increase of areas under cocoa, some of which is being interplanted amongst mature coco-nut palms.

Assistance to Planters.

Considerable assistance has been rendered to planters, not only by correspondence, but, whenever necessary, inspectors and instructors have been specially detailed to visit planters to render advice and assistance in cases of emergency apart from ordinary inspection patrols.

Seeds and Plants.

Many seeds and plants of economic and ornamental value have been distributed to planters, missions, Government stations, and to various parts of the mainland, particularly the mining district, for the adornment of growing settlements there. Seeds of specially selected strains of the best cocoa have been distributed to those planters desiring such.

Native Agriculture.

With the exception of inspection of native coco-nut groves by inspectors and instructors in the course of their patrols, native agriculture in connexion with annual crops like rice and peanuts has not increased to any extent. In the Gazelle Peninsula, there are 168 villages, the natives of which were being instructed in the cultivation of these annual food crops, with a certain amount of success.

Reports on the progress of the Sexava campaign and work in the Botanic Gardens and demonstration plantation are submitted *in extenso,* as the Director was absent on leave during the greater part of the year, and he is not in a position to give a full report from personal knowledge.

Agricultural Statistics.

The following statistics of areas under cultivation in the various districts of the Territory, show the predominance of coco-nuts over other crops:—

	All Crops. Hectares.	Coco-nuts. Hectares.
New Britain	30,466	28,321
New Ireland	27,944	27,781
Madang	13,653	13,424
Manus	9,177	9,176
Kieta	10,590	10,116
Sepik	2,531	2,531
Morobe	1,585	1,418
Total	95,946	92,767

REPORT OF THE ENTOMOLOGIST.

YEAR ENDED 30TH JUNE, 1936.

Up to 10th February, in the absence of the Director on leave, the Entomologist was Acting Director, and on the 24th February, 1936, he proceeded abroad on extended leave.

SEXAVA RESEARCH STATION.

In July, 1935, Mr. B. A. O'Connor, Assistant Entomologist, proceeded to Australia on recreation leave, returning in October of the same year. The essential work of breeding and liberating of parasites of *Sexava spp.* was carried on by Mr. A. W. S. Corfield during this period.

Leefmansia bicolor.

This Hymenopteron bred well in captivity, and was liberated on all sections of Arawe plantation and in several village groves in the vicinity.

By October, 1935, there was definite evidence to show that *L. bicolor* was breeding in the field in areas where liberated previously.

Doirania leefmansi.

Only a very attenuated colony of this species survived the delays in transport from New Hanover to Arawe, and very great difficulty was again experienced in breeding this Trichogrammatid under the conditions existing in the field laboratory. This was therefore discontinued in November, 1935, and the colonies in hand were liberated in the field.

Encyrtid sp. (from New Hanover).

This species continued to breed fairly well in the laboratory, and was liberated in the field with *L. bicolor.*

Mymarid sp. (from New Hanover).

Although a large number of Sexava eggs collected in the field on New Hanover were transported to Arawe in gauze cages, the transport delays proved too long, and the attempt to transport this parasite to Arawe failed completely.

From the high degree of incidence of *D. leefmansia* and *Mymarid sp.* in the plantations and groves on New Hanover, and the comparatively rarer infestations of Sexava on that island than in some other parts of the Territory, it appears to be highly desirable to test these two egg parasites of Sexava in some other locality where they are not yet present. As Manus is the most seriously infested district in the Territory, an attempt has been made to take these parasites to Manus by direct transport of Sexava eggs collected in bulk in the field on New Hanover, where, by placing them in the field in gauze liberation cages, this will give every opportunity for the parasites on emerging to spread direct into the surrounding coco-nuts.

Mokareng plantation will again be the first centre of operations.

In view of the difficulties of laboratory breeding of these species, as referred to above, this method appears to offer the best possibilities of establishing them in the new centre. In order to minimize the possibility of any one colony meeting with unsuitable conditions on arrival, *at least* five such colonies should be transported at approximately weekly intervals.

Mr. O'Connor travelled to Manus with the first colony, to ensure it receiving proper handling on arrival.

While the station is situated in the Manus district, investigations will be carried out into the incidence of *L. bicolor* in the field where previously established, the binomics of the other parasites transported from New Hanover, &c. Tests will also be made on the possibilities of the application of sprays, also costs, &c., of same. It is proposed to ascertain whether this method of attack has any possible application in the control of Sexava, more especially in the early stages.

GENERAL.

In September, 1935, Mokareng plantation, Manus, was visited by the Entomologist, where it was observed that the Sexava infestation, which had commenced to develop before the research station moved to New Hanover, has spread over most of the Salami end of the plantation. Sexava eggs collected prior to my arrival showed parasite emergence holes in a small percentage of eggs, but this was not as high as might have been expected.

Promecotheca antiqua.

In the early part of 1936, one plantation in the Kokopo district showed marked infestation by this Hispid. Control measures were carried out under the advice of the Entomologist, and a satisfactory control of the pest was obtained in a comparatively short period. The advent of dry weather completed the elimination of the pest.

The pest was reported to be bad in the vicinity of the Ring Ring plantation and on that plantation, and slight on Lindenhafen.

During the Entomologist's visit to Manus, *Promecotheca* attack was in fairly strong evidence at Lorengau, Salami and Lombrum plantations, and was reported from several other areas in that district.

Scolytidae in Kapok.

Shot-hole borers were reported from living kapok in one plantation. Investigation showed that the trees were planted in an unsuitable situation, and were decidedly sickly; this was most probably the cause of the attack as other kapok trees growing in a more suitable situation looked healthy and showed no signs of infestation.

Ant Control in Seed Beds.

A number of inquiries were made in reference to control of ants in seed beds, and chemicals and instructions were given for testing out against these pests. Only one reply was received; in that case the instructions had not been carried out, and unsatisfactory results were only to be expected.

Other tests with a sample of a proprietary preparation were very promising.

Tirathaba rufivena.

This moth was reported from several localities, and on one plantation in the Kieta district it was stated to be attacking young nuts after setting. The latter is not usual.

Sparganobasis subcruciata.

This weevil (base borer of coco-nuts) was reported by Mr. Corfield (Inspector and Instructor) from one locality on the south coast of New Britain, in neglected native coco-nut groves; in this case the infestation was as high as 3 feet from the ground in the trunks.

Brontispa froggatti.

Investigations into the bionomics of this pest were started in the insectaries in Rabaul.

Collections.

The entomological collections have been enlarged and maintained. Two collections have been forwarded to the Imperial Institute of Entomology, London, embracing the orders *Coleoptera, Hymenoptera, Rhyncota, Thysanoptera, Diptera, Lepidoptera, Neuroptera* and *Orthoptera,* in addition to *Acarinae.*

Four collections of identified species have been received from this Institute, comprising in all 106 species, embracing the orders *Coleoptera, Hymenoptera, Diptera, Lepidoptera* and *Rhyncota.* Several species new to science were represented.

REPORT OF THE ECONOMIC BOTANIST.

YEAR ENDED 30TH JUNE, 1936.

A considerable portion of the available time has been spent in visiting outside plantations and agricultural areas, both in an advisory capacity and to gain further experience of the flora, soil and climatic conditions which obtain over the widely-scattered areas of New Guinea.

The investigations carried out during the period under review were necessarily of a preliminary nature, and also most of the work carried on was in conjunction with other spheres of the Department's activities.

The completion of a new botanical laboratory and office, which is fully equipped with necessary apparatus and chemicals, will allow of much extension of work on botanical, and particularly plant pathological studies, as it is now possible to culture the pathogens.

The following article was published: "Derris. Its Culture and Economic Possibilities for the Territory of New Guinea", while another article, "A Survey of the Coco-nut Industry in the Mandated Territory of New Guinea", has been prepared for publication. (See *New Guinea Agricultural Gazette,* Volume 2, No. 2.)

Plant Disease Investigations.

Specimens of diseased plants brought in from time to time have been examined and identified as far as possible.

Some very interesting discoveries regarding the incidence of coco-nut diseases have been confirmed. It appears that chlorotic diseases associated with soil deficiency are very important here, especially on old plantations. Under these conditions fungi such as *Thielaviopsis, Pestalozzia palmarum, Helminthosporium spp.* and other weakly parasitic fungi gain the ascendency and hasten the decline of particular areas. It is seen that the fronds die off from the base while the few remaining fronds present a feathery and very unhealthy chlorotic appearance. In late stages the top falls over, leading to a condition not unlike bud rot. This condition is serious in New Guinea, and is the subject of further investigation.

During the visit to Bougainville Island and other islands, numerous areas of what are constantly referred to as "lightning struck areas" were seen and investigated on most of the plantations visited. It did appear that this condition was relatively scarce on young planted areas and was more prevalent in certain districts than in others. Bleeding of the stems was noticed (association with *Thielaviopsis*) and the foliage of the affected palms was usually drooping and withered with often the petioles split transversely. *Fomes spp.* and *Polyporus spp.* were seen on the dead coco-nut stems, while *Marasmius palmivorus* (perfect stage) was also present.

At Inus, Numa Numa and Teopasino plantations, Bougainville, several palms were cut down and the fronds, and also the dead wood, thoroughly examined. Specimens from the worst affected palms were also microscopically examined.

This condition is found all over the Territory, but nowhere so serious as at Bougainville Island, where severe lightning storms were experienced in the wet season, e.g., Numa Numa reported that during eight months they lost 53 palms

spread over ten isolated areas, caused by new strikes and delayed effects of such strikes. This disease is apparently identical with Lightning Strike causing False Bud Rot, described by Sharples in Malaya.

A comparable disease, but apparently with a different primary cause, was seen at Malapau plantation, New Britain, where 300 palms were affected. This area had been badly burnt over several times, and the bases of the palms were badly affected. Stem bleeding was present on all of the palms, while the fronds showed the same drooping overhanging appearance as was seen in several lightning-struck areas in Bougainville. Microscopic examination of the fronds which died back from the tip showed that a species of *Helminthosporium* had spread through the area and only became serious when the vitality of the palms was low. Cultivation, cutting off the diseased fronds and manuring with ashes from the copra drier, made a decided improvement in this area.

The most baffling coco-nut diseases in New Guinea are the conditions of Frond Choke and Head Droop (Corkscrew or Cabbaging). These have been previously referred to, but it is noticed that it has a particularly wide spread in New Ireland. Microscopical examination has given no results. In the condition of Head Droop it is seen that the top bends over as a complete semi-circle, while the leaves are all bunched and twisted into a distinct rosette, with the lower leaves sparse, short and dying back. In many cases the whole stem may form a distinct loop, or in some cases becoming S-shaped. In the final stages there is failure to bear coco-nuts, while the spathes completely die back. These are not hereditary abnormalities, because many palms recover and may develop the condition more than once. As far as it is known virus diseases have not been recorded in coco-nuts, but from analogy are strongly suspected as the causal agent of the conditions mentioned, although some growers suggest that it is caused by an injury to the young bud, e.g., by insect.

As an addition to the list of coco-nut diseases recorded in New Guinea, which was published in the last annual report, it is to be noticed that Karl Rechinger, 1907, recorded *Macrophoma palmarum* on *Areca Rechingeriana* and on *Cocos nucifera* at Bougainville, Kieta, while he also found *Anthostoma cocois* on the leaf and midribs of *Cocos nucifera*. A new Bacterial Leaf Blight, Leathery Copra, associated with soil deficiency, and "Silver Leaf Disease," believed to be caused by an unidentified fungus, are also recorded by the present author. Ring Disease of immature coco-nuts was recorded by H. W. Simmonds in 1924. Dr. Noble found evidence of *Botryodiplodia theobromae* being associated with the disease, but could not say whether it was causal.

Coffee Diseases.

Coffee Rust, *Hemelia vestatrix*, has not been found in New Guinea.

Some very interesting observations were made on specimens of coffee derived from Keravat demonstration plantation and Vunalama, New Britain, also Rugen Harbour, and Dr. Kroening's coffee plantation, Bougainville. It was seen that in the coffee nurseries Thread Blight was serious—this was particularly the case at Vunalama, where old decayed leaf fronds were allowed to dry and shrivel up without being removed. These fell on to the young plants and constituted the focus for infection. Thread Blight (*Corticium Koleroga*) was rather bad in the

native areas at Keravat demonstration plantation. Leaf Spot caused by *Brachysporium* or *Helminthosporium spp.*, was seen to a greater or lesser extent on all areas visited.

Root rots are the most formidable diseases in the main coffee areas of New Guinea; this is because coffee was planted after new clearings, hence the wood roots, &c., had not completely decayed. Such vegetable matter served as a source of infection to the coffee. An excellent specimen of the well known root-rotting fungus *Rosellinia pepo* was collected, and also the perfect stage of *Fomes spp. Ganoderme subrugosum* (Pat et Boisd) was also collected in a couple of instances on coffee areas.

Chlorosis or die-back of the deficiency type of diseases is probably the main cause for the presence of numerous sickly and weakly bushes in the coffee plantations here, and naturally fungous pests are usually associated with the devitalized condition of the plants. It is most important that all plants with knotted roots be rejected in the nursery, as a large percentage of the chlorotic bushes in the mature areas had badly constricted and knotted roots, which led to restriction of the sap flow and thus affected the plants. Such plants are easily recognized in the nursery by the shrivelled and unhealthy appearance of the leaves, thus a good deal of costly replacement could be saved by selection in the nursery. Other causes of die-back and chlorosis here, and probably of more importance, are soil and manurial deficiencies, such as an inadequate supply of nitrogen or carbohydrates, which can only be resisted by promoting healthy condition of growth. An excellent example of such chlorosis was seen where approximately 10 acres of coffee was growing on an area with an underlying limestone hardpan, which had been deposited from solution.

HERBARIUM.

A drying house for specimens was erected in the Botanic Gardens. About 200 covers have been added to the collection, and where possible six specimens of each plant were collected for despatch to other countries.

Lane-Poole's valued collection was reviewed and classified according to his own notes. Proper facilities for storing specimens are being constructed, and some blocks of shelves are already on hand.

Investigations on Natural Products.

Parinari Laurini (the "Kusta" nut).

The fruits of this local tree have attracted considerable attention on account of the drying oil they contain, reputed to be not unlike Tung oil, and the oil has been the subject of chemical investigation. Specimens of the nuts were sent to Kew Botanic Gardens and to the Imperial Institute for further examination and report, as it is also worth investigation from a perfumery viewpoint. The mashed kernels are used by natives for stopping holes in canoes and for fixing spear heads.

New Guinea Rattans (*Calamus spp.*).

Numerous experimental shipments have been sent to various manufacturers in Austraila for report as to their suitability for furniture-making. The reports so far are not promising, but much work remains to be done to prove what future

there is for the product. Comprehensive botanical collections, for proper identification of the species concerned, are being made. Also, more attention to preparation and selection of the best canes is necessary for future shipments.

Lalang or Kunai Grass (*Imperata arundinacea*).

Is known to compare favorably with Algerian esparto grass for paper-making. Some Australian firms are seeking concessions to exploit this product in New Guinea, where large areas of kunai grass exist. Cutting an experimental area in Rabaul indicated that a yield of about 3 tons per acre per annum could be expected with two cuttings per year.

Native Fibre Plants.

The fine strong fibre derived from a climber (*Crytostegia spp.*) is widely used in Bougainville and New Britain for making very fine and strong fishing nets, which will last three years in salt water. Specimens of the fibre were sent to Kew.

Gnetum gnemon.

The bark of this native tree is also widely used, particularly in Lavongai, for the same purpose.

Cephalohibiscus Peekelii and other spp. used for making strong ropes and small bags. Some excellent specimens were collected.

A species of Pandanus is used on the Mortlock Islands for weaving fine samples of cloth, which is both strongly and neatly woven on crude looms.

The fibre derived from native *Musa spp.* is also used widely in native work on Bougainville Island, and this could be a valuable commercial product.

Elan. Homalium foctidum (Roxb.) Bent. *Flacourtiaceae.*

One of the finest hardwoods from Lovangai was identified by Kew Botanical Museum. This is a very large forest tree which grows to a height of 100 feet, and at maturity has a diameter of about 10 feet. This is being sold for commercial purposes by the Leper Quarantine Station.

Two trees, native to Lavongai and suited for timber purposes, were identified as *Glochidon Novo-Guineense* (native name Kenem) and *Terminalia spp.* (native name Eiraula).

A species of *Elatostemma* (*Urticacaea*) was sent is as a weed suspected of being poisonous to cattle. It would appear that the hairy nature of the foliage would render it rather indigestible.

INVESTIGATIONS AND VISITS TO OUTSIDE AREAS.

The first visit during the current season was to the Leper Station at Anelaua Island, and to the leper quarantine area at Taskul, New Hanover, and a comprehensive report was submitted. The objective of this visit was to advise the authorities on methods of controlling soil erosion, which was very serious on Anelaua Island. It is the intention to make these stations as self-supporting as possible, and agriculture plays a big part in the community life of the stronger patients; hence advice was given on rotation of crops, utilization of forest resources, &c. Much suitable planting material was later supplied by the Department of Agriculture to these stations.

In September an extended visit was paid to Bougainville Island, and in addition plantations at Namatanai, New Ireland, Nissan Islands and Buka Island were visited. Particular attention was paid to Rugen Harbour coffee plantation, Raua, and a report furnished, but on almost every plantation from Raua to Buin boundary some investigations were made. In the virgin areas at Hakau plantation, which are now being developed for coffee and cacao culture, the soil is rich and the forest covering heavy. Reports were furnished on diseases observed and various other aspects of coco-nut culture.

Later in the year a second visit was made to Amalgamated Coffee Plantations Ltd., at Vunalama, New Britain, and a report submitted. Attention to shade regulation has much improved the planted areas there.

The development of coffee culture here since 1930 has been promising and worthy of note, as about 1,200 acres are now planted to this crop and more areas are being planted (e.g., at Hakau). Rugen Harbour and Vunalama plantations are now coming into bearing, and are at a most interesting phase of development. In both instances the first coffee beans despatched was within two and a half to three years from the date of planting. When accurate costing and production figures are available, it will be possible to indicate the future possibilities for large-scale coffee-growing in this Territory.

An experimental area of about 10 hectares of Jackson's Hybrid coffee is yielding well at Rugen Harbour. In India this is known as Arabian Hybrid, but is not so well liked as Kent's Arabica Hybrid, some seed of which has been introduced and isolated in two situations by the Department of Agriculture; seed should be available for distribution in three years. It is believed that the development of high quality coffee production at high-level situations in this Territory should be worthy of much attention.

AREAS DEVOTED TO ECONOMIC CROPS, RABAUL.

The land in the economic section had been subject to rather serious denudation and erosion, so it was decided to level the area in addition to providing a large drain to carry off all surplus waters coming from the hills behind. This levelling work is about two-thirds completed; but, owing to the depth of soil removed, crops will not grow well, hence it has been necessary to bring the soil back into production by cover cropping and manuring.

Three large nurseries have been erected, one of which has been completely planted to coffee seedlings. These nurseries are also designed for budding and grafting work with cocoa, citrus, mangoes, and so on, to supplement the work carried on at Keravat and for teaching the more intelligent natives how to do this work. Provision is being made for improved seed storage facilities. It is also interesting to note that manure derived from the Rabaul town night soil, and treated by the Indore fermentation process, is being used on this section. There is provision made for using several tons per week when transport facilities are available.

An interesting experiment on propagation of citrus varieties and species from cuttings was carried out in nursery beds under calico covering, both stem and root cuttings being used. Tahiti lime, *Citrus medica* and *Citrus lemonia* all struck well, and although only a small percentage of sweet and sour oranges grew, these were from softwood cuttings, whereas the hardwood cuttings did not grow. Varieties of mandarins failed completely.

In addition to the fruit areas at Keravat, a more comprehensive but smaller collection is maintained in Rabaul. Last season superior varieties of *Achras zapota*, namely Sawo kollon and Sawa manila, were introduced from Java and transplanted to the economic orchard.

Two superior varieties of mangoes (Paw Paw and Kinara) were introduced from Queensland, and were transplanted to the fruit section. In addition to these, some valuable introductions, consisting of the Aravel, Urumahue, Puero, Rare, and Uruhuroro varieties of seedless breadfruits introduced from Tahiti, were planted out in two separate areas. As the natives are keen on some other improved varieties of seedless breadfruits just coming into bearing here, numerous root cuttings were made for distribution, and tried in various areas. Arrangements are also completed for grafting superior types of mangoes, of which seven varieties were introduced in German times, and to seedling stocks for the same purpose.

Budded superior varieties of Rambutans introduced from Java were sent to Keravat demonstration plantation, while others more recently introduced are being planted at Rabaul. Selections of *Bertholettia excelsa* (Brazil Nut) were introduced by the Director of Agriculture from Singapore, and also further stocks of selected Derris of known high rotenone content. Numerous marcots of superior Pomeloes and Rambutans already in bearing were propagated by the Nurseryman. Some introduced Mangosteens are well established.

Most important introductions last season were seeds of the following types of Cinchona (quinine):—

Cinchona ledgeriana.
Cinchona succirubra.
Cinchona robusta.
Cinchona hybrid.

These were introduced from Amani, East Africa, and from the Manager, Government Cinchona Plantation, Kalipong, Burma. Arrangements were made and nursery beds prepared at Ramu Post, Morobe district, to receive this seed, at an elevation of 5,200 feet.

General Plant Breeding.

Close co-operation with the work at Keravat demonstration plantation has been maintained, and good progress has been made with work carried on in conjunction with the Superintendent.

The programme of coco-nut improvement by close breeding and selection inaugurated last season has been much extended by using coco-nut selections derived from the most representative districts and plantations in New Guinea.

Vegetative propagation of cocoa selections first made by the Superintendent was commenced, and by approach grafting in the nursery 100 per cent. take was recorded at Keravat. It is necessary to increase these selections into vegatative or clonal families before their relative value is absolutely determined on a comparative basis. Approach grafting was also successful on a large scale with old trees at Rabaul, where seedlings of a strong Forastero hybrid stock was used. This work was again further increased on established trees at Keravat under the supervision of the Superintendent. The ease and quickness of this method indicates its value to planters, especially as it can be done by natives. Budding work is also to be commenced, as it is known that the Criollo cacao present in

New Guinea is equal to any in the world, and should flourish better on a strong hybrid stock—this experimentation is proceeding.

The numerous Java coffee selections introduced last season from the coffee-breeding stations have been planted out in separate plots for observation prior to further breeding work being carried on.

Re-selection has been carried out within the earlier-introduced and well-known Java coffee numbers Bangelan 105, 01 and Soembar Asim 78.11. This means that there is now much improved Robusta coffee seed available for distribution. Selections are also available from the Jackson's Hybrid and from several Keravat numbers.

The practical method of selective re-grafting was also commenced in the old coffee areas, and newly-appointed inspectors and instructors, together with some intelligent natives, were employed on this work. It was at the beginning of the dry season that the grafting commenced, and most success was attained in the more heavily shaded areas, due to the shade and moisture present. Bangelan 105,01 was used for grafting over the inferior bushes, which had been cut back earlier and one or more shoots allowed to develop.

Patch budding with kapok, using two intelligent natives for the work, was very successfully attempted, using spreading Bondowoso 5 on Java seedling.

Some selection work was carried out by the single tuber method in the various varieties of sweet potatoes (*Ipomoea batatas*) both at Keravat and Rabaul.

BOTANIC GARDENS—RABAUL.

The gardens have been well maintained and many new additions and improvements made. The nurseries have been re-arranged with all new beds properly lined out and well constructed. The existing plant houses have been repaired and roofed over with new bamboo lattice work; the cement foundations were also strengthened.

Although the watering facilities have been increased by the provision of new pipe lines, the water storage capacity is totally inadequate to sustain the gardens over the dry season. Plans have been drawn up with the intention of remedying this position.

A considerable number of large epiphyte orchids was received from Bougainville and Manus and was displayed in various positions in the main gardens.

One area at the approach to the Director's house was terraced and much improved by the establishment of ferns, Diffenbachias, Caladiums and other shade-loving plants. The introduced plants in the rockery, laid down during the previous season, have made a very fine display and filled up a large area where lawn grasses did not flourish. One large rockery was also laid down last season in the valley nearest No. 2 Garden House facing the main pathway, while two raised beds were also established in adjacent areas. This has again filled in an area where much silt collected and few plants were growing.

Carlodovicia palmata, Pandanus variegata, Strelitzea and various other plants were also used very successfully in densely shaded areas.

In close proximity to the avenue of *Glyricidia maculata* stretching through the centre of the gardens the ground was very bare, hence a representative collection of shrubs was planted to improve this area, with good effect. Near the centre path, where much washing was formerly evident, two well designed and terraced rockeries have been constructed.

The large and new expanse of lawns and shrubs laid down in the garden facing Malaguna-road has considerably improved the appearance and orderliness of the central areas. It is rather unfortunate that a great proportion of the tourists travel through the pathway at the head of Mango-avenue, and proceed to the nurseries and aviary without seeing the true scope of the Botanic Gardens. Considerable attention has been paid to this section, however, and beds of annual flowers, newly gravelled pathways, low hedges, extra potted plants and so on, have been provided.

In other areas of the gardens the provision of climbing plants on bare trunked trees, e.g. *Parkia spp.*, and on the *Spathodea alata* avenue, has effectively reduced the bare appearance. *Epripremum pinnatum, Calamus rotang, Bougainvillea spectablis,* &c., have been largely used for this purpose.

These gardens have maintained an extensive exchange with other botanic gardens and departments. Suitable collections of low land orchids were sent to Buitenzorg, Peradeniya and Singapore Botanic Gardens, and also a collection of tropical fruits to Queensland. Numerous other plants and orchids were obtained in exchange.

On his return from abroad the Director of Agriculture introduced a number of plants and orchids of economic and botanical interest.

The numerous new introductions brought in the previous season from Buitenzorg, Singapore and Hong Kong have in most cases been well established and have added a considerable variety of ornamental plants.

Although pest inspection has been regularly maintained, a number of the older palms were effected by palm weevils. A number of the very old palms appear to be declining, apparently owing to soil exhaustion, and much manuring and cultivation is rendered necessary.

Manuring with compost, adco and blood and bone is regularly carried out as is spraying where necessary. The gardens can use practically all the Rabaul night soil, treated by the Indore process. The new stand of the terrestrial orchids *Arachis maingayi*, and particularly *Vanda Miss Joaquin*, have been one of the features of the lawns in the central beds. The red flowering frangipanni from Mexico produced one of the most lovely blooms in this area as did the newly introduced *Arabidæa magnifica.*

A large collection of seeds and plants was forwarded for avenue planting in the township of Lae.

Avenues.

A line of natives was employed regularly on avenue work. On two occasions this line was increased and all the avenues systematically gone over and the dead and overhanging branches removed. This was particularly the case with Casuarina and Malaguna avenues.

The following new avenues were planted during the year:—

Kuanua-avenue—*Peltophorum inerme.*
Ulawun-avenue—*Cassis siemea.*
Park-street—*Lagerstroemia flos regina.*

The five new avenues planted the previous season were kept in order and replacements made where necessary. They were kept watered in the early stages. A plaited bamboo shade covering was placed over the avenue trees where required and particularly over the Royal palms in the Namanula-road.

REPORT ON THE DEMONSTRATION PLANTATION, KERAVAT.

YEAR ENDED 30TH JUNE, 1936.

During the year under review further economic development took place. An additional area of 24 hectares was cleared and brought under cultivation, and at the close of the year there were 92 hectares in cultivation and 17 hectares under secondary bush and ready for final clearing.

Approximately 1 mile and 10 chains of road was constructed, where necessary suitable avenue trees were planted, and bridges made from local hardwood timber were built across drains and creeks as the various sections of road were formed. The total road mileage at the close of the year was 3.6.

Long-term experiments were commenced in respect of coco-nuts, coffee and cacao, and short-term rotational and varietal experiments with annual food crops.

A native food area, comprising 12 hectares was maintained throughout the year, the crops being issued for food purposes to the labour and to supply outside demands.

Provision was made and sufficient areas maintained for the supply of economic seeds and plants.

Further coco-nut, coffee and cacao selections were made, and seed from selected mother trees was planted in the nursery.

Nursery and field trials were made in respect to the budding of kapok and the grafting of coffee and cacao.

A series of experiments was conducted in cacao fermentation and curing and the results have been published in the *Gazette*. A costing experiment with groundnuts was also made, and the data obtained is being compiled for publication.

During the year frequent visits were made to the plantation by the Economic Botanist who is collaborating in experimental work.

Native Labour.

The diet of the labourers was continually varied, the rice ration being supplemented by taro, yam, cassava, sweet potatoes and green maize. Bananas, paw-paw, pineapples, groundnuts and mature coco-nuts when available were issued in addition to the normal ration. The preserved meat or fish ration was supplemented with fresh fish, a total of 6,384 lb. being issued during the year.

Visitors.

Exclusive of departmental officers, 340 visitors to the plantation during the year were accorded advice and instruction.

Meteorology.

The rainfall during the year was the heaviest yet recorded, and totalled 124.74 inches, the heaviest falls occurring in November (14.97 inches), January (14.34 inches) and March (17.41 inches).

Precipitation was registered on 225 days, an average of 18.9 days per month.

PERMANENT CROPS.

Cacao (Thepbromae cacao).

Maintenance work in connexion with this crop was carried out during the year.

A further number of trees came into bearing, and it was possible to make further selections and commence a new series of curing experiments.

Yield records were kept of the mother trees; the yields of trees Nos. 2, 4, 12, 13, 14, 15 were exceptional between the periods 29th October, 1935, and 1st June, 1936, and were as follows:—

Tree No. 2	13.0	lb.	dry	commercial	cacao.	
„ No. 4	15.7	„	„	„	„	
„ No. 12	15.0	„	„	„	„	
„ No. 13	12.1	„	„	„	„	
„ No. 14	20.4	„	„	„	„	
„ No. 15	16.3	„	„	„	„	

Two acres that were prepared during the latter half of last year were planted experimentally with selected seedlings for yield comparisons.

Two acres were interplanted with coco-nuts and the area was laid out on an experimental basis.

The 7 acres that at the end of last year were in the course of clearing and preparation for a yield, and spacing trial of selected seedlings, were planted during the year.

The preliminary clearing of five hectares commenced last year for planting Criollo cacao was completed and 889 seedlings have been planted to date.

One series of curing experiments was completed and the results published in the *Gazette*.

"Approach" grafting trials were conducted in the nursery and field, and proved successful. A number of Criollo seedlings was grafted on hybrid stocks in preparation for planting in the Criollo cacao section.

Coco-nuts (Cocos nucifera).

Maintenance of the coco-nut area was carried out during the year and an additional 8 hectares were planted.

A long-term breeding and selection programme was instituted in collaboration with the Economic Botanist. One 5-hectare block is being cleared and planted as required. At the close of the year seed nuts from 25 mother trees selected on five estates throughout the Territory had been planted. Seed nuts from a further 25 mother trees selected on three other estates are in the nursery awaiting germination before transplanting.

Catch crops and cover crops were planted in the new areas as clearing and planting progressed.

Collection of insect pests and treatment of infested palms was maintained.

Nine King coco-nut selections were made, and seedlings planted as a windbreak on the northern end of the Criollo cacao block. The selections consist of six "Green" variety, two "Yellow" variety, and one "Red" variety.

Coffee (Coffea spp.).

Cultural methods were maintained throughout the year, and further selections were made by the Economic Botanist. There are now—

16	selections of	Keravat Berry	(K.B.)
10	„ „	Keravat Berry-Stock	(K.B.S.)
3	„ „	Keravat Stock	(K.S.)
8	„ „	Keravat Robusta 78.11	(K.R.78.11)
8	„ „	Keravat Bangalan 105.01	(K.Bgn.)
6	„ „	Keravat Jacksons Hybrid Berry ..	(K.J.H.)
3	„ „	Keravat Jacksons Hybrid Stock ..	(K.J.H.S.)

A new nursery was constructed and 9,572 seeds of the various selections planted. An area of land sufficient to accommodate 2,975 seedlings was cleared, holed, and planted with temporary and permanent shade, preparatory to planting out the above selections on an experimental basis.

A certain amount of grafting in the field was conducted towards the latter half of the year in order to observe the best periods and methods of grafting to adopt. Observations showed that a certain degree of shade is required, in the field, and that nursery grafting would probably be more economic as the shade conditions can be controlled. Arrangements were therefore made when planting the new nursery for ample material to be available to carry out complete experiments under nursery conditions.

Harvesting of the main block continued throughout the year, and the yield up to the 1st June, 1936, was 2,443 lb. of hulled coffee which was sold locally at an average price of 9d. per pound.

An area of 2 acres, prepared last year for a variety trial of imported strains and Keravat selections, was planted.

Oil Palm (Elaeis guineensis).

The whole area under oil palm is yielding well, and cover crops have been established in the four blocks. Regular pruning was carried out every three months during the year. Neither pests nor diseases were troublesome during the year, although two palms affected with a form of "Bud rot" were destroyed.

Fruits.

General maintenance of the fruit section was carried out.

New plantings, consisting of sixteen mangosteens, *Garcinia mangostana*; twelve rambutans, *Nephelium lappaceum*; four sawo-koelon, *Achras zapota*; four sawo manila, *achras zapota*; four duku, *Lansium domesticum*; four mundu, *Garcinia dulcis*; four durian, *Durio zibethinus*; two mlindjo, *Gnetum gnemon*; one nangka-nangka, *Artocarpus integrifolia*; two sukon, *Artocarpus incisa* (seedless); two duku, *L. domesticum*; and eight bilimbing spp. *Averrhoa carambola* and *A. bolimbi*. All these varieties were brought from the Dutch East Indies by the Economic Botanist. N.B.—*Gnetum gnemon* is also native to New Guinea.

The citrus fruits were kept clean, weeded during the dry season and the cover crop allowed to re-establish during the wet season.

In April, 1936, sulphate of ammonia at the rate of 2 pounds per tree was applied to the oranges and lemons, and the same quantity of sulphate of potash was applied to the grapefruit and mandarins.

Tropical fruits, such as rambutan and avocoda pear, bore crops during the year; contrary to expectations the mango varieties did not bear. The Queensland paw-paw section was increased, also the Hawaiian paw-paw area. Pineapples continued to bear prolifically, the quality of the fruit, however, being only mediocre due possibly to the abnormally heavy rainfall. The banana area produced fruit throughout the year; the bunches were well formed but a big percentage of the fruit was damaged by insect pests.

ROOT CROPS.

The principal root crops under cultivation during the year were: taro, cassava, yam, mammee, sweet potato, and Jerusalem artichoke. All, with the exception of the latter, were utilized for native food purposes and to supply demands for seed.

The yield and palatability trial laid down in April, 1935, was continued, and certain varieties were rejected after the first harvest.

Seed of three new varieties of "Taitu" yam was introduced from the Trobriand Islands.

Sweet potato selections were made, and three strains definitely fixed. Single tubers of each of these strains were planted for multiplication purposes. Attack by the larvæ of the moth *Hippotion celerio*, occurred frequently throughout the year, and some measure of control was obtained by dusting with arsenate of lead. The sweet potato weevil (*Cylas formicarius*) was responsible for reduction in yield and damage to a big percentage of tubers.

Small demonstration areas of the minor crops such as *Canna edulis* and *Maranta arundinacea* were kept under cultivation.

ANNUAL FOOD CROPS.

Rice was kept in constant cultivation during the year; one large area was practically destroyed by heavy wind and rain in January, 1936. A fungus possibly *Helminthosporium spp.* was very prevalent, also a species of *Hemiptera*. The variety trial laid down in March, 1935, was a failure on account of disease.

Maize cultivation was maintained throughout the year, to provide native food and seed requirements.

Ground-nuts were in continual cultivation. "Red Spanish" and "Pearl" varieties being mostly used. A costing experiment with "Red Spanish" ground-nuts was carried out, and the crop which was forwarded to Australia for sale realized 3.5 pence (3½d.) per lb. Two new varieties of ground-nuts were introduced from Rhodesia and are growing well. Issues of ground-nuts were made from time to time for native food purposes; seed was also supplied for native agriculture and plantation requirements, and shelled nuts sold to local Chinese in Rabaul.

FIBRES AND SPICES.

Demonstration areas of the principal fibres and spices were maintained. Fibres under cultivation are—Manila hemp, sisal hemp, sansevieria hemp, pine-apple hemp, banana hemp, sunn hemp, jute, kapok and cotton.

The spices comprise—Cinnamon, clove, pepper, ginger, tumeric, and capsicums. The pepper and ginger sections were increased during the year.

DRUGS AND INSECTICIDES.

Small demonstration areas of tobacco, cocaine, *Tephrosia vogelii*, and *Hydnocarpus anthelmintica*, were kept in cultivation.

A section containing Derris spp. and selectedt Derris from Singapore, was cultivated for observation purposes, and portion of the area was harvested at the close of the year preparatory to forwarding samples overseas.

COVER CROPS.

Cover crops were extensively planted during the year, particularly *Pueraria javanica, Mimosa invisa, Centrosema pubescens, Calopogonium mucinoides,* and *Aeschynomene americana.*

The species of cover crops now under cultivation comprise: in addition to those listed above; *Psophocarpus palustris, Pachyrrhizus erosus, Dolichos hosei, Desmodium scorpiurus, Phaseolus spp.*

GREEN MANURE CROPS.

The chief green manure crops are cowpea, *Crotalaria anagyroides, Tephrosia candida, Clitoria cajanaefolia,* and ground-nuts. In addition *Cajanus indicus, Tephrosia vogelii,* and *Canavalia spp.* are kept in cultivation.

Sufficient areas of the above crops were maintained to supply seed for the plantation and outside requirements.

SHADE TREES, WINDBREAK TREES.

For the cultivation of coffee and cacao, both temporary and permanent shade trees are used. The former are chiefly *C. anagyroides* and *T. candida,* and the latter *Leucaena glauca, Albizzia sumatrana, Erythrina micropteryx,* and *Erythrina glauca.* The three latter permanent shade varieties were introduced during the year and are being used for comparative purposes with *L. glauca.*

In the spice section, species of *Leucaena, Albizzia, Adenanthera, Gliricidia,* and *Peltopherum* are used for demonstration purposes.

Trees such as *Pithecolobium saman, Pelthoporum inerme, Cassia siamea,* and *Hydnocarpus anthelmintica* were planted during the year to form windbreaks and to function to some extent as shade.

BUILDINGS.

A new barn constructed from native material and measuring 30 feet by 22 feet, an office, laboratory, hospital, and store with sliding roof were erected during the year.

AN ARGUMENT AGAINST COPRA CUTTING.

G. E. Bliss.

It is remarkable that, despite the continued discussion of coco-nut planting in all its branches, from the planting of the seed nut to the drying, inspecting and marketing of copra, there is one stage of the industry that has received very little attention. I refer to the preparation of the green meat for drying or, as we term it, copra cutting.

The present system (except among those few who have adopted the "Ceylon Drier") is, indeed, practically taken for granted, and it is not generally realized that we have unwittingly adopted what is merely a slovenly native method: a method that is a relic of the days when the European was a trader and collector rather than the planter and producer. It is a method unknown anywhere but in the South Seas and it is, I suggest, the main reason why the copra from those parts has been relegated to its lowly position on the world's markets.

The co-operative efforts of planters and copra inspectors have raised the price of Rabaul Hot Air copra to an average of about 20s. above that bedrock price, but we are still a very long way down the list. In brief, Rabaul Hot Air, the best of the "cut" copras, is still below the worst sun or hot air dried copra produced from the half nut. Below (it must be emphasized) copra produced in countries where the industry is almost entirely in the hands of natives.

Fully 90 per cent. of the copra shipped from this Territory is produced under direct European supervision which is a far larger proportion than elsewhere. We have the advantages of good driers, a high standard of plantation management, and a sound system of inspection. If *all* the stages of production were brought up to date there is no reason why our copra should not rank among the leaders.

There are three outstanding reasons why the "half nut system" produces better copra.

No sweating of copra in bags. Under present conditions a large amount of copra reaches the drier in a hot, slimy state. Half nuts can be placed on the drier as soon as broken.

No sweating in the drier. Hot air can circulate through loosely piled half nuts better than through even a thin layer of cut copra.

Elimination of dust and small pieces. A constant cause of complaint by buyers.

In addition to the improvement in quality, there are these further advantages.

No loss in the field. Under the present system this loss probably varies from over 5 per cent. to 2 per cent., according to the efficiency of the cutters and the strictness of their supervision. But some waste always occurs—the excellent condition of the plantation pigs (and of the kanaka pigs from villages adjoining) testifies to this.

Less loss in the drier. This is least in hot air driers with moveable trays, but even there is probably as much as 2 per cent. On smoke driers and those types of kilns where the copra is trampled on and turned with shovels it is undoubtedly very much larger. There is also an appreciable loss in the form of dust and sweepings when bagging.

(Careful and impartial tests under plantation conditions would be necessary to form an accurate estimate of the total avoidable waste caused by copra cutting. The writer's own experiments and observations have convinced him that the average is in excess of 5 per cent. Nor can this percentage be considered petty since it represents, on an average year's total production, about 3,000 tons—a very worthwhile saving.)

Better fuel. Any manager, whether employing kilns or smoke driers, who has suffered one wet season is eloquent on the difficulties and delays caused by sodden husks.

Less soil exhaustion. Husks are a wasteful and inefficient fuel but (without the shell) form a useful mulch and a valuable source of humus.

Fewer mosquitoes. Every half husk, with shell attached, is a potential mosquito breeder. Without the shell they are harmless.

It is realized that a change from the existing method will involve some difficulties, particularly in the initial stages. No attempt to alter the methods and habits of our conservative minded labour is ever easy, but it is felt that the benefits outlined above will well repay the trouble.

There would no doubt be a slight increase in the cost of production at the outset, but this should gradually disappear as the labourers become more adept.

Except for the saving of waste before mentioned, the financial benefits would not be immediately apparent: the results would be gradual as was the case when copra inspection was first instituted. Indeed it might even be necessary to class copra so prepared in a separate, higher grade. But such copra should eventually reach the price standard of Ceylon—and the stigma "South Seas" be, at last, definitely removed from copra produced in this Territory.

HUMIDITY.

Humidity is one of the main climatic factors, which is closely correlated with temperature and rainfall, also with the proximity to the Equator or the Poles, altitude, prevailing winds, &c. When the absolute humidity of the atmosphere reaches a certain percentage at a particular temperature, precipitation occurs and rainfall results.

The atmosphere might not be saturated at a particular temperature but a decided drop in temperature such as happens, when moisture laden winds encounter high mountains and come in contact with the cold air surrounding these mountains, will lead to saturation at a lower temperature and thus precipitation occurs.

The distribution of the rainfall in particular areas of New Guinea may mainly be attributed to this fact, e.g., during the north-west season the north-west portion of the island of New Britain receives much more rain than the south-east portion. Conversely when the south-east winds prevail the south-east portion of the island receives most of the rain.

As compared with Australian weather records the humidity of New Guinea is considerably higher and more constant, also the temperature and rainfall. New Guinea does not experience that "rest period" that winter gives in Australia which is so essential to most fruit trees. This amplifies how important a control the weather conditions have on the agricultural possibilities of a country.

The continual humidity in New Guinea leads to development of rain forest growth. The plants comprising the flora have particular adaptation for transpiration of moisture, and further their flowers are often concealed and protected from the effects of excessive moisture on the pollination.

Meteorologists put forward the theory that rain forests increase the rainfall. When rain falls on a forest, a percentage of it is detained by the crown and trunks of the trees and re-evaporated into the air, thus further increasing the latter's store of moisture. If, then, a moist current strikes this cooler column, it is condensed and rain occurs. Unfortunately in the tropics we have no reliable data to prove this.

Differences in atmospheric humidity are closely associated with occurrences of lightning, especially near high mountains. In this case increase in electrical potential is recorded where the warm air from the sea coast, and plantations situated there, carrying dense masses of water vapour from the sea is forced up the high mountain slopes and the electrical charge increases with condensation. It is easily seen why some areas, close to high mountains and near the sea, are more liable to lightning storms than others.

METEOROLOGY.

AVERAGE MEAN RELATIVE HUMIDITY.—ALL COASTAL STATIONS (31.12.36).

Readings as at—	No. of Years.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Year.
RABAUL (CAPITAL—T.N.G.).														
4° 12′S., 152° 11′E., Gazelle Peninsuala.														
9 a.m. ..	19	79	79	78	79	78	77	77	74	71	69	72	76	76
3 p.m. ..	..	74	73	73	75	73	71	71	69	66	68	71	73	71
9 p.m. ..	..	93	93	94	94	93	91	90	88	87	89	92	94	92
KAVIENG (NEW IRELAND).														
2° 34′S., 150° 49′E., N.W. Coast of New Ireland.														
9 a.m. ..	18	81	81	81	82	81	80	80	80	78	78	79	80	80
Saturation.:														
3 p.m.=100	..	77	75	75	78	77	77	75	74	74	74	75	77	76
9 p.m. ..	..	86	86	88	89	90	90	89	90	88	86	87	86	88
KIETA (BOUGAINVILLE).														
6° 13′S., 155° 39′E., E. Coast of Bougainville.														
9 a.m. ..	19	79	80	80	81	81	82	81	80	79	77	76	76	79
3 p.m. ..	..	79	78	78	79	79	79	79	78	77	76	77	77	78
9 p.m. ..	..	84	84	84	85	86	85	85	84	84	84	83	81	84
MADANG (MAINLAND) MADANG DISTRICT.														
5° 11′S., 145° 48′E.														
9 a.m. ..	18	84	84	83	86	84	84	84	82	82	82	82	83	83
3 p.m. ..	..	77	77	77	75	75	75	75	75	75	75	76	77	76
9 p.m. ..	..	89	88	87	89	88	87	86	85	85	85	87	88	87
MANUS (LORENGAU).														
2° 2′S., 147° 19′E., N. Coast Manus.														
9 a.m.	12	87	87	84	88	87	88	89	88	86	85	85	86	87
3 p.m.	..	76	73	71	75	74	76	74	72	74	71	72	75	73
9 p.m.	..	91	90	89	92	92	91	92	91	91	92	94	92	91

THE DISEASES OF COCO-NUTS (COCOS NUFICERA) IN NEW GUINEA.

By R. E. P. Dwyer, B.Sc., Agr., Economic Botanist.

Introduction.

This article is intended to present a preliminary account of the important fungus and physiological diseases affecting the coco-nut palms in the Mandated Territory of New Guinea. The author has not had a lengthy association with local conditions, hence the investigations and the observations outlined are to some extent inconclusive. Although several investigations were made previously by officers of this Department, it is only recently that a suitable well-equipped laboratory for plant pathological work has been available. It is considered, however, that sufficient data and recorded observations, although incomplete, are on hand to be of sound practical value to the local coco-nut planters; these may prove of general interest to investigators and others interested in the coco-nut and copra industry. A good deal of the information presented has been gleaned from unpublished departmental reports. Further, a study of the literature available from other countries proves most illuminating when their findings are compared with what obtains on plantations in this Territory.

It is pointed out that, although the diseases here associated with fungi, physiological causes and soil deficiencies have not been investigated to any great extent, up to the present time, this work is gradually being expanded by the Department of Agriculture. The aggregate losses due to these causes may not be so noticeable as those due to insect pests, particularly the leaf-eating types, but their effects are always present. It is certain that the physiological effects due to soil deficiencies and such diseases as "lightning strike" causing "false bud-rot" are amongst the most serious conditions affecting coco-nut palms in this Territory. It is known that coco-nut palms with reduced vigour, due to any causes whatsoever, become more liable to fungus attack, hence soil condition, drainage, cultural conditions and general health of the palms are usually intimately associated. It must be remembered that injuries and wounds caused by insects often open the way for severe fungus infection, thus aggravating any damage already done.

BUD-ROT.

According to investigators bud-rot is generally regarded as a serious disease in most tropical countries. Ocfemia[48] states that bud-rot has been recorded in Portuguese East Africa, Ceylon, India, Malabar, Florida, U.S.A., Trinidad, Jamaica, British Guiana, The Philippine Islands, and several other countries.

One of the first records of an epidemic disease of coco-nuts was from the West Indies in 1934. Heavy losses occurred in Jamaica from 1891 to 1910 and at about the same period in Trinidad.

In the Phillipines the disease spread very rapidly and the coco-nut planters became alarmed because their plantations were threatened with destruction. Through the efforts of Dr. Copeland[24] in Laguna (1908) an act was passed requiring that all coco-nut trees infected with bud-rot be cut down and burned. The disease has been considered serious in the Territory of New Guinea and is the subject of legislation, hence it is believed worthy of detailed discussion.

Bud-rot was proclaimed under the "Plantation Diseases and Pests Ordinance of 1916" in the Laws of this Territory[33] as a disease subject to inspection by qualified officers of the Department of Agriculture. Remedial measures were laid down, and penalties provided for in case of non-compliance with the provisions of the ordinance. In the ordinance the indications of bud-rot were stated as follows:—

"Withering and turning brown of the central shoot (which can then be easily pulled out by hand) followed (or occasionally preceded) by the decay of the other fronds, and a soft, vile, putrid, brown rot in the heart, followed by the whole top falling off leaving only the bare trunk."

Approved combative measures cited were: Immediate felling, cutting up and burning of affected palms, together with spraying of all palms and ground within a radius of 150 feet with Bordeaux mixture.

It is now generally recognized that bud-rot may be due to a variety of causes, hence evidence of the power to infect is necessary to establish the existence of any specific bud disease in a particular country of locality. It also appears necessary to differentiate between the rotting of palm buds and true bud-rot diseases. As bud-rot may be brought about by so many causes it represents a condition resulting from a number of such causes rather than a specific disease.

There have been several individual records of bud-rotted palms occurring in this Territory, not including those now known to be associated with lightning-struck areas. The incidence of these bud-rotted palms led Dr. Bryce[13-18] (late Director of Agriculture in New Guinea) to suspect that true bud-rot was present in this Territory. So far as one can gather from the records, no actual fungi or bacteria which could be held responsible for the disease were isolated. He described the condition of bud-rot[13] in a departmental leaflet and mentioned that in New Guinea this disease had been reported from New Ireland, New Hanover and the Vitu Islands, and was no doubt generally distributed in the Territory.

Phytopthora faberi, which several authors consider to be identical with *Phytopthora palmivora,* was described by the same author[17] as being present on cocoa here, causing purple canker and pod rot. This was significant, as bud-rot in India,[19] Philippines[56] and other countries is usually attributed to the fungus *Phytopthora palmivora.* Thus it was legitimately considered that where *Phytopthora* was present on cocoa it would most likely be found on coco-nuts.

Ashby, S. S.[6] stated that, although the *Phytopthora* of pod-rot and cacao in the West Indies appear to be the same species as that on the coco-nut, it is not believed to be the same strain, since the form from the palm has not been found able to rot cacao pods.

The Bud-rot Position in other Countries.

The position in New Guinea, however, is, in the author's opinion, analagous with what occurs in Malaya where *Phytopthora spp.*[59-61-62] is found attacking many plants, but was seldom seen on coco-nuts. As an illustration, Thomson, Malaya[78] inoculated 40 coco-nut palms just above the bud with different strains of *Phytopthora* isolated from coco-nut, cotton, rubber and cacao but only one positive result was obtained with *Phytopthora palmivora* from a coco-nut derived from India. Dr. Muller[44] stated personally that bud-rot due to *Phytopthora faberi* was practically of no importance in Java or the Moluccas and that only a couple of cases of probable infection had been reported.

The present author has not so far seen this fungus on coco-nuts here, although on one case of spear die-back of oil palms a fungus thought to be *Phytopthora spp.* was seen.

Stockdale 1906[75] pointed out that a proportion of the bud-rot occurring in Trinidad was purely secondary in its nature, being a consequence of the failure of the palms brought about by so-called root disease. This was later proved to be red ring disease[46] due to infestation with a nematode worm.

Johnston 1912[37], came to the conclusion that *Bacillus coli* (Esch. Mig.), or an organism indistinguishable from it, which was capable of causing rot of soft tissues of the coco-nut plant and which is perhaps responsible for coco-nut bud-rot in the Phillipines, was due to *Phytopthora faberi,* and that the bacterium coli was not the cause of epidemic diseases there. He found that infection could be obtained through the growing point with cultures of this bacteria, but only in the case of severe injury or excessive dampness. Bryce 1924[13] stated that it was rather an open question as to whether *Bacillus coli* is in this instance more than secondary, i.e., follows the *Phytopthora* attack and completes the ruin of the palm.

Ashby 1924[4] expressed the opinion that there were two bud-rots in the West Indies, one fungoid caused by *Phytopthora* and one bacterial caused by a bacillus, probably a strain of *Bacillus coli,* but there is some doubt as to definite proof. (*See* also discussion by Elliot[27].)

Tucker 1925[80] in "Porto Rico" isolated an organism resembling *B. coli* from diseased buds, but the results of his inoculations were negative. He reproduced the disease *Phytopthora faberi,* with or without wounding.

Dr. Butler, Director of the Imperial Bureau of Mycology, at the Imperial Botanical Conference, July 1924[20] indicated that he was of the opinion that *Phythopthora palmivora* was the only vegetable parasitic organism which had been proved to cause the destructive bud-rot of palms and was capable of attacking perfectly healthy palms and inducing severe epidemics of disease.

Stapp, 1928[73] stated that it remains to be determined whether coco-nut bud-rot is due to bacteria or fungi or both. Alston 1924 and 1925[1] British Guiana, stated that a disease, which was responsible for the dying out of the coco-nut palm in certain localities, was falsely designated by the name bud-rot for the reason that the bud was, as a general rule, the last portion of the crown to become affected, whereas in true bud-rot, a disease caused by a species of *Phytopthora,* the earliest and most characteristic system was infection of the bud followed by collapse of the whole central whorl. A similar condition called "bud-rot disease" practically identical with the above was described from Trinidad.

At the Imperial Botanical Conference it was suggested that the term "coco-nut wilt" be applied to these occurrences. Briton Jones 1928[9] distinguishes two forms of the root disease of coco-nuts recorded by Stockdale[75] and Nowell[46-47] in Trinidad, which he named respectively "bronze leaf wilt" and "yellow leaf" or "tapering stem wilt". The latter is distinguished by a yellow discolouration of the leaves progressing from the tip backwards while all the leaves, including the central ones, become dwarfed. The latter is a chronic malady and its history and effects have not yet been worked out; its described symptoms are very similar to those described by Park as caused in Ceylon by a root disease

associated with *Macrophomina phaseoli*. The symptoms described also resemble the tapering stem and chlorosis is believed to be due to soil deficiencies present in New Guinea.

The Director of Agriculture, Mr. Murray[45], who recently saw these occurrences in Trinidad, feels certain that the bronze wilt does not exist here; and does not think that the tapering stem disease is the same as the one found in this country.

Smith 1934[71] Jamaica states that in Montego Bay area a form of bud-rot in which no fungal pathogen appear to be actively indicated has caused severe damage.

Identification.—The following description of bud-rot is culled from various publications. The first visible indications of the disease are the falling of the young nuts on the palm and the withering of the youngest leaf: there is no known way by which the earliest stage of the infection may be detected as, when the first visible symptom, or the browning of the young leaf, occurs, the growing point is already rotted. The young emerging leaf becomes yellowish brown or light brown and projects upwards sword-like from the crown. The leaf dies because the softer part of its base is completely rotted, and if pulled firmly can be drawn out from the crown or inclosing leaf sheath. At the base will be found a soft grey or brownish mass of rotting material which emits a vile smell. The stench is apparent on merely walking past a diseased palm. If the diseased palm is allowed to stand the youngest leaves become involved and soon die, the oldest leaves being the last to be affected, at which stage the bud or cabbage is completely decayed. The dead central leaf is often first broken by the wind (believed to be more typical in *Phytophthora* infection) and may fall to the ground. The older leaves may remain green and retain their usual position for several months, but as they die they are not replaced, and finally the trunk is left bare.

Only the soft parts are affected, the hard trunk and the roots remaining healthy, but once the bud is destroyed the whole palm of necessity dies. Often the young spathes are rotted in the same manner as the bud, and often the young racemes of flower heads will be found dead when the spathe opens. A close examination of these dead racemes will show that they are invaded by the fungus at their bases. Sometimes, but not in this case, rows of dark brown spots across the pinnae or leaflets may be seen, due to infection by *Phytopthora*.

Nowell, 1921,[46] described bacterial bud-rot and stated that this does not affect the central bud alone, but may commence anywhere in the crown, either at the base of the leaves or inflorescences or on the tissues between them. It never extends far on the leaf stalk nor does it affect the woody part of the stem. Only in exceptional cases does it travel more than a foot or two into the softer central portion of the stem below the crown. It was pointed out that typical bud-rot also follows rapidly on the death of healthy trees from poisoning or severance of the stems.

Sharples, Malaya 1924,[59] at the Imperial Botanical Conference indicated that some factors associated with severe attacks of bud-rot in Malaya are injuries caused by Black Beetle (*Oryctes rhinoceros*) or Red Stripe Weevil (*Ryncophorus Schach*), and tidal floodings occurring in fields adjacent to rivers where sufficient protection had not been made to prevent the entry of water. According to reports submitted to the same conference[5-19-25-47-59] swampy conditions of the soil give

rise to a condition which results in bud-rot. Droughts may give rise to a similar condition, as may ill-defined root troubles. It was also asserted by some that the planting of immature nuts may cause a kind of bud-rot.

Emphasis was placed on the fact that growers of coco-nuts must not rush to the conclusion that cases of bud-rot on their estates may be caused solely by parasitic organisms. Good cultivation, good drainage and satisfactory manuring are likely to result in a reduced number of cases of bud-rot in palms. Correct agricultural methods would result in smaller losses from pests and diseases, although some epidemics are bound to occur.

Bud-rot in Fiji.

Simmonds, in 1921 and 1922,[63-64-65] describes an outbreak of bud-rot in Fiji, which he considered to be true bud-rot and as this is one of the South Sea Islands it is of more than usual interest to New Guinea planters. He stated that the disease seems to have been present in Fiji for at least ten years, but did not cause much anxiety until the years mentioned, when a large number of palms were destroyed on account of it. The disease was almost confined to the wetter portions of the group, where it was commonly found on the back parts of the estates along the foothills. The central heart rotted, leaving the outer leaves and ring of nuts apparently healthy.

When an affected palm was cut down and the outer leaves removed separately a greenish brown or yellow spot was seen, and this communicated with the central portion of the tree, the whole of which was found to be rotten and in a very foul smelling condition.

The investigations largely dealt with an outbreak at Taviuni, from which Dr. Garment[33] conducted microscopical examination of the diseased specimens. He found bacteria associated with each, but believed the occurrence to be secondary. In a culture of diseased tissue he found a fungus which appeared to resemble closely *Phytopthora palmivora*. The Imperial Bureau of Mycology, in reporting on a similar specimen, could only identify the fungus as an intra-cellular *Phycomycete* (fungus group) whose mycelial characters may be similar to *Phytopthora* as no fruiting bodies were present.

Both Simmonds[2-65] and their Inspector of Plantations commented that the older coco-nuts growing near the sea shore are attacked very slightly, but that the disease was most prevalent on young coco-nuts following a strip of land at the bases of the foothills. This was a region of continuous rainfall and frequently of poor drainage, thus the coco-nuts were growing under unfavorable soil and climatic conditions. This indicates a more potent cause of apparent bud-rotting, and it is believed by the present author that this is comparable with some of the areas seen in the heavier soils of New Ireland some distance from the beach.

Some Examples of Reported Bud-rot Infected Palms in New Guinea.

In May, 1921, at Talasea, New Britain, a plantation inspector stated that he noticed six trees suffering from what he considered was bud-rot, although no microscopical examination was made, and that many more palms had been destroyed previously.

An inspector for the Expropriation Board, in September, 1921, sent in a specimen from New Ireland from a palm which had earlier been attacked by Rhinoceros beetle; this was not considered sufficient to destroy the palms, which undoubtedly died from cabbage rotting. Several palms were affected in the same

way and were within a few yards of one another. The symptoms appeared to be the same as bud-rot except that the smell, although very pronounced and persistent, may not have been typical. (The author believes that this was probably a case of lightning strike.)

It was also stated that although palms with rotten cabbage had previously been observed it was thought that most of the cases were caused by beetles entering the cabbage. The soft tissues had been exposed to infection from bacteria and other sources which set up a rot.

Over 600 palms, most of which were destroyed, were reported to have been affected by beetles and red palm weevil on one plantation and a fair number of these showed rotting of the cabbage.

At Talasea in March, 1922, the District Officer cut down a two-year old palm, because when standing near this palm a powerful and peculiar odour was plainly discernable. No trace of beetle or weevil was seen, although the heart leaf was obviously rotting and the outer leaves drying off. On being split open the kernel of the bowl and lower stem was filled with a creamy coloured pulpy and rotten mass of semi-liquid consistency. From the outside the trunk or bowl appeared healthy in appearance and was not punctured. It appeared, however, that the disease did not develop from the cabbage. Newport (then Acting Director of Agriculture) in reporting on this occurrence said that the condition described is occasionally met with in this Archipelago. It may be a kind of bud-rot, but does not tally exactly with the recognized bud-rot in other countries, where the older palms are usually attacked.

The characteristic smell of true bud-rot somewhat resembles bad eggs and bad onions, while the smell from this palm resembled the putrid decay of ordinary vegetable matter together with the sour smell of fermentation. He believed the case to be a local bud-rot (herein classified as sporadic bud-rot) which is not infectious and could be due to accidental causes.

Some isolated cases of what appeared to be true bud-rot were recorded from Namatanai, New Ireland, in the same year. In December, 1924, a plantation Inspector reported cases of what were believed to be bud-rot on two plantations in the Witu group and the symptoms were described as follows:—

"The disease appears to be a form of bud-rot and the first noticeable sign of the disease on a palm is on the second or third line of fronds, where the tips of one or more fronds die back a distance of two or three feet and hang down (C.f. leaf break).

Running down the midrib of these affected fronds, a dry rot, brownish in colour, was noticed and this rot extended down the midrib a foot or eighteen inches past the point from which the tip is hanging. On one plantation, three palms, killed by this disease, were cut down and carefully examined. At the base of the cabbage a circular mass of cream coloured rotted tissue, about 6 inches in diameter was found which, when cut open, gave off a very offensive smell. It was noticed particularly that only the terminal shoot and the surrounding undeveloped leaves were absolutely dead and dry, while the lower fronds still remained green. Extending down the trunk from the base of the cabbage a dry brown rot was found which in one instance extended to a distance of twelve feet, while the trunk below this area was exceedingly dry. The roots appeared quite healthy and no traces of beetles were found. The whole area where these palms were discovered was isolated and kept under observation."

The Plantation Disease and Pest Inspector, from the Department of Agriculture, was then sent to Witu to describe the disease and reported as follows:—

"The disease is similar to that which was seen on one plantation in the Bainings district of New Guinea in 1922. The first indication of the disease is odd fronds broken in the centre, otherwise the palm appears to be perfectly healthy, the central frond was found to be dead but still standing upright. The palm has a very sickly appearance, about half of the fronds being broken in the centre and the *whole cabbage leaning over* becoming gradually worse until the whole of the cabbage collapses (C.f. head droop or lightning strike). The fronds have a dark brown colouring running through the central stem to the point of fracture. The centre of the cabbage is full of a creamy rot or substance which gives off an offensive odour. The rot can be traced down the centre of the trunk for from 6 feet to 9 feet and occasionally up to 12 feet from the cabbage. This rotted area takes the form of a funnel, tapering off from about 6 inches in diameter at the top to a very fine point as it travels down the stem. The trunk below this is practically devoid of sap and is very tough. Palms which are newly affected appear to be very dry when the stem is cut. The affected area is on low-lying ground about 20 feet above the sea—odd affected palms being located on swampy ground near the beach."

Bryce 1925[18] wrote regarding this disease at Vitu Island, and stated that from the description the disease is undoubtedly bud-rot. He also said that the danger of rapid spread of this disease is great, and that preventive measures should be undertaken immediately and drastically applied. The diseased or dead palms should be cut out and burnt, particular attention being paid to the destruction of the bud and corm."

It should be noted that it is not clear from the records whether the terminal shoots died first, further that the occurrence was confined to particular areas. No casual organisms were seen and in view of recent findings it is not unlikely that this was a case of "False Bud Rot." Nevertheless, this conclusion must be open to doubt when expressed by one who did not investigate the occurrence. The macroscopic (visible) characters were somewhat suggestive of true bud-rot, though the fact that no further spread was reported seems to discount this possibility. According to the description it appears that some "Head Droop" may have been present, also the low-lying soil conditions described would have been unhealthy for palms. It is clear that such records of bud-rotted palms led to the conclusion that epidemic bud-rot was probably present in New Guinea.

Definition of the "Bud-rot" Problem.

Sharples 1928[61] in defining the coco-nut disease position stated that up to 1918 the coco-nut disease position was largely influenced by the results published by Johnson[37] in his work relating to bud-rot. The uncritical acceptance of Johnson's inoculation results has led to much confusion as according to Nowell[47] and Briton Jones[9] the technique of inoculation was faulty as the infection stands were made in holes 45-cms. deep bored into the tender tissues at the crown of young coco-nut palms grown under glass. Thus it is evident that not much else was needed to cause their death.

The results of Sharples' 1924[59] inoculation experiments proved that numerous widely separated organisms other than members of the genus *Phytopthora* were capable of producing typical "bud-rot" symptoms when stab-inoculated

directly into the cabbage or bud, hence wound inoculation may be unsatisfactory in elucidating the causes of bud-rot.

It is evident from a study of the literature that the investigations on the bud-rot position have been very complex and difficult to follow even in other countries. It is thought essential that the true position regarding the occurrence of bud-rot in New Guinea be expressed.

Although suspected at various times, as far as is known no authentic occurrence of true infectious or epidemic bud-rot has been recorded in New Guinea, with the possible exception of the record from Vitu Island. The coco-nut palms here which have been believed to be bud-rotted and recorded as such fall into three groups as far as can be determined.

1. False bud-rot, due to lightning strike or fires, which is described elsewhere.
2. *Palms which suffer from tapering stem,* presumably due to soil exhaustion, leading to eventual collapse and dying back of the cabbage. This may be associated with root disease but no proof seen. *See* discussion on deficiency diseases.
3. *Sporadic bud-rotted palms,* where the disease is, in most cases, secondary to injury by animals such as rats, mechanical injury, insect injury, &c.

There may be isolated cases of bud-rot due to fungi or bacteria, but these are very scattered, if present at all, and so far no fungi have been isolated from so-called bud-rotted tissues. After a recent severe attack of *Promecotheca antiqua* on one plantation in New Britain, many palms withered up and lost their cabbage, leading to death of the palms. It has been demonstrated that when bacteria of the *Bacterium coli* group are introduced into very young buds through injuries or insect punctures, they can develop in the soft nutritive tissue and cause a destructive rot.

Injury to Coco-nut Palms by Lightning—a cause of "False Bud-rot."

An editorial in the *Malayan Agricultural Journal* (preface 61) referring to coco-nut diseases in Malaya made a statement which is mainly true for this Territory—"As a result of a study of the literature and text books from other tropical countries it has frequently been assumed that the cause of death of coco-nut palms in Malaya was due to attack by fungi, recorded as casual agents or bud-rot and root diseases in these other countries.

True bud-rot has never been recorded in Malaya, and no definite root disease of coco-nuts has so far been found in this country. Only one instance of a disease in which symptoms comparable with those described for true bud-rot has been observed in Malaya. On this occasion, it was found that the decay of the bud tissue had been caused initially by pellets fired from a shot gun. (A case of sporadic bud-rot.)

In the case of coco-nut palms, no organisms have been found to be primarily responsible for the only form of bud-rot recorded in Malaya. It has now been established that in Malaya the cause of this form of 'bud-rot' which affects coco-nut palms is injury by lightning. The symptoms of the disease do not resemble true bud-rot as reported from other countries since the central leaves and the buds are usually only affected after the outer leaves have died.

It was established[59-61-62] that the association of the fungus *Marasmius palmivorus* (also present here), which was previously suspected of being casual in its effect, was only secondary, this fungus simply accelerating the defoliation of the stricken palms and having nothing to do with the actual rotting of the tissues."

On most plantations in the scattered islands of New Guinea, numerous areas, constantly referred to as "lightning struck", have been seen and investigated and such occurrences have also been mentioned in earlier reports.

The evidence shows that this condition is undoubtedly identical with the occurrence of "lightning strike" causing "false bud-rot" which has been described in Malaya[56]. The incidence of these areas is widely spread and although found in all parts of the Territory is nowhere so much in evidence as at Bougainville Island (one of the Solomon Islands group) and on parts of the mainland, where severe lightning storms are experienced during the wet season. It is a significant fact that several areas in New Ireland and Tabar are rarely affected by lightning strike, and usually where this does occur few palms are affected.

On one plantation in Tabar only two cases of lightning strike have been recorded, one which affected four palms and another eight palms. On several plantations practically no lightning strike has been seen. There are no high mountains in the vicinity and the soils are of a different type from those where lightning strike is prevalent.

During the eight months period ending April, 1936, the manager, Numa Numa Plantation, reported that 53 palms spread over ten isolated areas were lost by new lightning strikes and delayed effects from earlier strikes. At four other large plantations on this island several lightning-struck areas comprising from ten to twenty palms in each area were investigated. Several palms were cut down and the fronds and also the dead wood thoroughly examined. Specimens from the worst affected palms were brought to Rabaul for microscopical examination.

Lightning-struck areas are familiar to most planters here because they are readily discernible even in the early stages. The affected palms are usually present in a circular area around the focus of the strike. The palms which receive the full strike usually die first, but the surrounding palms may live for some time before they are killed by delayed effect following the lightning. The affected palms present a dried-up appearance, while the fronds hang down loosely and, although dried up, remain attached to the palm. Bleeding of the stems is noticed and is usually associated with borers and the fungus *Thielaviopsis*. It appears, however, that the burning effects of the lightning are sufficient to induce bleeding from the trunks. The fronds of the affected palms, in addition to being drooped and withered, often have the petioles or leaf stalks split transversely. *Fomes* spp. and *Polyporus* spp. were seen on the dead wood of the affected palms and *Marasmius palmivorus* (perfect stage) was also present. In the worst cases the bark readily strips from the cortex, and in the dead palms in some cases a good deal of black fungus mycelium was evident when the skin or outer layer was removed; the cut timber showed some reddening in the vascular bundles and only a light reddening in the central internal fibrous and conducting tissues. The fronds (boms boms) were badly drooping on the palms showing delayed effects and often the pinnae (leaf divisions) were apparently burnt back to the midrib, cf. bitten leaf disease described by Nowell[46]. This could be expected to be due to lightning strike, but was usually associated with *Thielaviopsis*. There was no false bud-rot

on the palms cut down, but it was seen on other palms where the cabbage rotted and an objectionable smell was noticed. The individual palms in most cases appeared to die from the outside inwards and not from the inside outwards, which is also comparable with similar occurrences recorded by Sharples in Malaya[86].

On one estate here some recently struck palms were seen in a triangular area near two houses where pigs were fed. A fence and a small railway line converged near this spot, where conditions should be favorable for lightning conduction—apparently two palms were affected by the direct strike while several surrounding palms were showing delayed effects. An occurrence of a similar nature, where about twenty Areca palms situated very close to a barbed wire fence were injured by lightning, is recorded from the Coco-nut Experiment Station, Klang, Malaya. The central palms usually die first, but the outer palms in an affected area may persist for six months or in some cases recover entirely, thus the condition of bud-rotting mentioned is not an immediate development. A departmental instructor says that he has actually seen the palms after a vivid and strong flash of lightning and was able to select the central palm affected, as the inside fibres of the trunk were exposed. Plantation owners here have actually seen the ground lifted and the roots exposed, with the grass burnt above, by lightning, showing one means of transferring the charge from one palm to another, i.e. by the wet surface roots where the ground was very moist.

The following reasons for the particular susceptibility of plantations in portions of Bougainville Island to lightning strike are advanced.

Firstly, the percentage of magnetite or magnetic iron present in the soil is said to be fairly high. In Buin (south of Bougainville) Waterhouse personally stated that he saw areas of virgin bush forest comprising several trees struck at the one time, although usually only a couple of trees are affected.

It has been found that the electrical potential in the region of lofty mountain peaks is often very high. Increase in electrical potential is recorded where the warm air from the sea coast and plantations carrying dense masses of water vapour from the sea is forced up the high mountain slopes and the electrical charge increases with condensation. Thus there would be more liability to lightning near such a high mountain as Mt. Balbi (10,170 feet). Although under moist conditions the potential need not be so great as in dry atmosphere the causes here are more pronounced.

In England, where electrical research is carried out, it has been shown that probably 2,000,000 or 3,000,000 volts are required to produce a 12-ft. flash of lightning, hence such a high charge could be expected to affect a fair radius of palms. Lightning, according to recent findings, does not occur as in one flash but in a semi-oscillating series of flashes and behaves as an electric spark on a large scale. It has been seen by sparks on a lightning conductor which was not actually struck that a small but rather constant charge may be earthed when the atmosphere is heavily charged with electricity.

The chemical effect of a lightning discharge is considerable, e.g., a considerable quantity of ammonium nitrite (NH_4NO_2) is formed in the air and washed into the soil, but this is not harmful. There are, however, small quantities of nitric and nitrous acid liberated which may have an immediately deleterious effect before they react with other chemicals present in the soil. In any case it can be quite understood that lightning will affect the vitality of the palms in close proximity to the strike, because of the highly-charged atmosphere in the vicinity, although they might not receive the direct charge.

On Kar Kar (Dampier) Island, a volcanic island which is about 50 miles in circumference and rises in the centre to a peak of 4,900 feet, the condition of lightning strike is very prevalent. On one plantation on the mainland well over 1,000 palms have been destroyed by lightning, and as many as 45 palms were affected in the one area. There were high mountains behind and the situation on a peninsula led to pronounced differences in electrical potential.

Effects of Burning-off in Relation to Disease.

There is the question as to whether conditions similar to those which exist in lightning-struck areas can be brought about by other causes, which is difficult to answer. The occurrence of a comparable condition in about 300 coco-nut palms at one plantation, in New Britain, suggests that fires may bring about effects similar to lightning strike. These palms were situated in a depression at the back of the plantation and appeared naturally stronger than in the soil exhausted areas in the immediate vicinity. This area had been badly burnt over several times and the bases of the palms were badly affected. Stem bleeding was present on all the palms and the leaves showed the same drooping, overhanging appearance as is seen in the lightning-struck areas in Bougainville. Microscopical examination of the fronds which had died back from the tip showed that a fungus, a species of *Helminthosporium* with at least two spore forms, was present. The disease was seen to begin at the tips of the leaves and work down the edges of the pinnules, finally affecting the whole pinnule (leaf division). The dead fronds on older palms remained attached to the palms while the centre midrib became silvery or blackened in appearance. The lesions were not scattered but showed a brownish halo near the edges, where the brown diseased tissues joined the green, apparently unaffected tissues, thus the appearance was not the same as when *Pestalozzia palmarum* is present.

The seriousness of the disease became apparent only under unfavorable conditions when the vitality of the palms was low and whose decline was hastened when the shade lessened and Kunai (*Imperata arundinacea*) began to spread. Obviously only hygienic and cultural methods designed to increase the vigour of the palms could be advocated, as there was no direct treatment available which could be considered economical. The advice in this case was to strip off all the ripe nuts and affected fronds (bom boms) and burn the latter, the work being commenced on the outside of the affected area. In addition, a large circle of ground was dug up around each palm so that the cover crop present was given a chance to grow. Ashes from the drier and some other organic manures, plus a later application of basic slag, made a decided improvement in the diseased area.

Such injury to the palms where rubbish, grass and so on has been burnt around the base of the palms is not uncommon in New Guinea and, in addition to the direct injury, the added danger from insect and fungus pests is very considerable. Any burning off in plantations should be carried out carefully and it must be remembered that recurring accidental grass fires in a lalang (or kunai) infested plantation may have the same effect.

Lightning Storms in Relation to Diseases of Coco-nuts.[86]

The subject of lightning strike and its connexion with false bud-rot is of great importance to local planters, hence the liberty is taken of quoting Sharples' findings on this subject from 1928-33, almost verbatim[88].

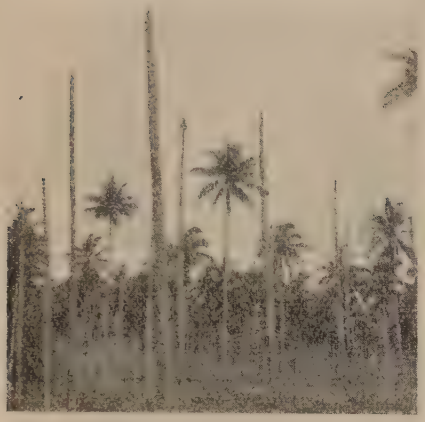
False Bud-rot due to Lightning Strike.

* In Malaya evidence has been adduced which proves conclusively that the form of "bud-rot" found in that country is the direct result of lightning strike. This form of bud-rot is characterised by the central shoot being the last part to die, the outer leaves droop and turn brown long before this occurs.

The areas affected can be divided into—

(*a*) Small areas of common occurrence.

(*b*) Large areas of rare occurrence.



COCO-NUT PALMS KILLED BY LIGHTNING STRIKE.

LIGHTNING STRIKE. N.B.—Central palm just dead. Ring of 12 palms killed.

(*a*) Small areas affected by lightning. The typical cases, locally known as bud-rot due to lightning strike, show a group of ten-twelve trees, of which one, two, or three central trees die rapidly; on examination the bud tissues are found to be in a badly decayed condition. The surrounding trees show disease symptoms of varying intensity, e.g., stem bleeding, broken and hanging outside leaves, with the central leaves and spike still standing erect. When left untreated some of the slightly affected trees gradually grow worse and finally succumb.

* Copied almost verbatim from A. Sharples, *Annals Applied Biology*, XX., 1, pp. 1-22, February, 1933.

The leaf symptoms of the slightly affected trees can be conveniently described here. The broken leaves are in some cases found with the break taking place about 2 feet away from the distal extremity, so that the tip of the leaf hangs down. Such damaged leaves are termed "tipped." Others show the break taking place about the point where the basal leaf pinnae join the petiole, about 3-5 feet from the stem, and the whole of the leaf stalk carrying the pinnae hangs

LIGHTNING STRIKE.—Palms destroyed by lightning.

LIGHTNING STRIKE.—Palms destroyed by lightning.

down. "Broken" leaves is a convenient term for such leaves in contradistinction to "tipped". Leaves breaking away from the stem at the base but remaining attached and hanging against the stem are termed "hanging" leaves.

(*b*) Large areas affected by lightning. The large areas of affected palms, groups in which over 100 affected palms may be found, are of very rare occurrence.

The first was examined in 1923, when 80-100 palms were found showing symptoms exactly similar to affected palms in the small patches. On the same estate in 1926 a larger area, showing between 200 and 300 trees, was found. This incident caused much concern, because of the possibility that the area affected in 1926 might be considered a re-infection from the 1923 area.

In dealing with this outbreak great precautions were observed to prevent spread as a result of diseased tissues being transported down the drains. The possibility of a severe root infection could not be ignored, and the usual isolation methods were recommended. The area was trenched off and no fresh cases of diseased trees have yet been reported outside the isolated area.

Theory of Lightning Discharge and its Significance in Disease Problems on Malayan Plantations.[86]

As mentioned above, the symptoms shown by the affected palms and the sequence of events so far met with in the larger areas are exactly similar to those found in the smaller areas, where the evidence for regarding lightning as the primary initiating cause is so strong. Lacking a satisfactory explanation, the only cause for congratulation was that the large affected areas occur at rare intervals. Three have been studied up to date, one in 1923, one in 1926 (both of which occurred on the same estate), and one in 1928. In 1929 the Twentieth Kelvin Lecture was delivered before the Institute of Electrical Engineers by G. C. Simpson, C.B., F.R.S., and his subject was "Lightning." The lecture had many points of interest in view of the position in Malaya with regard to lightning strike and bud-rot of palms.

Dr. Simpson, in his exposition, distinguishes three types of discharge—

(1) The discharge within the cloud.
(2) The discharge to the ground from a positive cloud.
(3) The discharge to the ground from a negative cloud.

He states that the two latter are of most importance to the electrical engineer, for it is these which strike buildings and overhead wires and do structural damage.

The characteristics of the two types of discharge to the ground are very different. The discharge from a positive cloud starts high up in the atmosphere and branches out on its way to earth. An earth-connected object may therefore be struck either by the main "trunk" or by one of the "branches." On the other hand, a discharge to a negative cloud starts on an earth-connected object, which takes the whole discharge.

The theory leads to the conclusion that discharges from positively-charged clouds would be frequent but weak, while discharges from negatively-charged clouds would be infrequent but very strong. Dr. Simpson stated a further conclusion, i.e., that there are at least four times as many discharges between positively-charged clouds and the ground as between negatively-charged clouds and the ground, and there are good reasons for believing that the ratio is nearer 10:1 than 4:1.

Applying these conclusions broadly in relation to lightning strike on coco-nut palms, two important points are immediately obvious. Discharge from positively-charged clouds will be frequent but weak. These frequent but weak discharges

can be considered as responsible for the numerous small groups of coco-nuts killed during practically every month of the year; in connexion with these conclusive evidence has been obtained of the direct connexion between the typical symptoms and lightning.

Discharges from negatively-charged clouds will be infrequent but strong. These infrequent but strong discharges allow a convenient and fitting explanation for the occurrence of occasional areas of coco-nut palms being killed out, although there is no direct evidence of the connexion between the two. The symptoms shown by the affected palms in the small and large areas are so exactly alike that only one conclusion can be drawn, and that is that the causal agent is the same in both cases. Until the appearance of Dr. Simpson's paper caution was necessary in the absence of any direct evidence or fitting explanation, but now that the phenomena experienced on coco-nut plantations can be fittingly connected up with physical phenomena, there seems no reason to doubt the adequacy of the explanation. Many diseased areas have been visited personally, and the general trend of events is found to be similar in all.

The conclusion can be stated with absolute definiteness that lightning is of primary importance in the causation of disease on plantations of *Cocos nucifera* in Malaya. This statement gains added point from the fact that not only is lightning the source to which false bud-rot has been traced, but definite evidence has been obtained to show that it must be considered to be the initiating cause of many cases of stem bleeding and root disease of coco-nut palms. The symptoms of these diseases have been found to be purely secondary, appearing in trees slightly, but not visibly, affected by lightning on some previous occasion.

Delayed Effects.

Coco-nut palms in a lightning-strike area may show no visible signs of damage at the time the badly-affected palms are killed, but succumb to a form of root disease several months afterwards. There is little doubt in these cases that the palms were adversely affected by the lightning, which was responsible for the death of the badly-affected palms on a previous date. Many cases of this type are wrongly diagnozed as root disease; the initiating cause is lightning, and the root trouble secondary.

Similar records apply to palms in lightning-strike areas which show very slight traces of stem bleeding at the time the badly-affected trees are killed. "Stem bleeding" is due to a reddish liquid which exudes through discoloured cracks in the external stem tissues. A small boring beetle, *Suprosites pygmaeus* Har., commonly attacks palms suffering from stem bleeding, and cases have been found which show but slight signs of stem bleeding, but several months later the bleeding had become suddenly profuse, and the palm died rapidly. In one instance, two palms 14 chains away from the nearest badly-affected palms, suddenly succumbed, twenty months after the strike. Similar observations have been made recently in Malaya by Thompson.[78]

This evidence has been obtained to show that the common diseases of coco-nut palms in Malaya may originate through lightning injury. Three diseases have

been recorded from other countries, and are considered to be separate and distinct. The diseases and their causes as listed at the present date are—

Disease.	*Cause.*
(*a*) Bud-rot	*Phytophthora sp.*
(*b*) Root disease ..	*Banoderma lucidum* (*Leyes*) *Karsten.*
(*c*) Stem-bleeding disease	*Thielaviopsis paradoxa* (de Seignes) v. Hohnel.

In the writer's opinion, the positive evidence for the connexion of the disease and the cause thereof in (*b*) and (*c*) is not very convincing, and, in view of the facts recorded in this investigation, must be accepted with caution. With regard to (*a*), there is no evidence in Malaya up to date to show that a *Phytophthora sp.* is associated with the problem as a causal agent.

Treatment.

It is obvious that the occurrence of lightning strike cannot be prevented. Such treatment as pasting thick lime wash over the stems and spraying has been tried and proved both ineffective and costly.

Treatment should be more concerned with preventing any delayed effects from lightning injury in surrounding palms.

It has not been proved whether there is any spread of fungus infection through the roots of dead palms, but the possibility is there; the use of trenches to isolate diseased from healthy trees would prevent that condition only. It is provident that these affected areas seldom extend naturally beyond a certain limited distance before the condition is checked.

The idea that the soil on lightning-struck areas is poisoned and will not grow new palms for some time may be due to the fact that the matted root system and any fungi present would retard healthy growth.

Control Measures (recommended by Sharples[59]).

Although these measures were advocated before it was recognized that the effects of the fungi are largely secondary to the lightning strike, the only possible precautions which could be taken are outlined.

Accumulation of dead and decaying material must be avoided, as fungi fructify more in wet weather; hence during wet periods greater care must be taken.

Spraying methods cannot be recommended owing to difficulties in reaching the fungi present.

The only methods that can be adopted are the usual sanitation methods, designed to clear away vegetable debris and decrease atmospheric humidity in the places where the fungus is growing strongly. Control measures for affected tall coco-nut palms will be similar in, (*a*) cases of typical lightning strike, (*b*) in the areas where large numbers of palms showing similar symptoms are affected, and (*c*) in areas where the palms are retrogressing owing to unsuitable growth conditions.

In cases (*a*) and (*b*) the dead and badly-affected palms must be cut out immediately, and the leaves and upper parts of the stems destroyed. About 2 feet of the comparatively soft stem tissue below the cabbage should be treated immediately, as this part of the stem seems to be the favourite portion with the Black Beetle (*Oryctes rhinoceros Linn.*). Some palms which do not appear

badly affected on first inspection will later show more definite symptoms, and these also must be promptly treated. The leaf trunk should be piled, inspected and treated.

During rainy months burning is often difficult, but it is more necessary to take precautionary methods during wet periods because of the profuse development of the fructifications of any fungus present, with consequent liberation of millions of spores. If burning cannot be undertaken, the material should be piled in various places and inspection of these piles of decaying vegetable material should be made at intervals. If mushroom-like fruit bodies of fungi begin to develop, the piles should be drenched with a 5 per cent. solution of copper sulphate. The stems and roots should be cut up, split and piled and await convenient opportunity for burning (soaking with petrol or kerosene would assist the burning).

Slightly affected trees with leaves hanging, broken or tipped, should be cleared up by cutting off all leaves showing such symptoms. This will make supervision over these palms much easier, for, after cutting such leaves away, it will be easy to keep a strict tally and to judge whether affection is making progress by noting whether healthy leaves, previously intact, become broken or tipped. The cut leaves should be treated as indicated above and firing done as soon as weather permits.

In areas where the palms are retrogressing, owing to unsuitable growth conditions, the badly-infected trees should be treated similarly. Most affected leaves are hanging, but few are broken or tipped. These affected leaves should be cut away and treated as indicated above. On these areas large accumulations of decaying vegetable matter are always present; this decaying material should be collected and destroyed.

In conjunction with these sanitation methods, measures designed to improve soil conditions should be undertaken. There is little definite knowledge regarding methods to be adopted, but applications of lime and fish manure have, in some cases, brought about definite improvements in twelve to eighteen months' time.

In concluding this discussion, one can state fairly conclusively that there has not been any record of a true infectious or epidemic bud-rot occurring in New Guinea.

Briefly, the supposed bud-rot infections recorded in this Territory could be determined, in most cases, as being either "false bud-rot" due to lightning strike or fires, or palms which suffered from "tapering stem" primarily due to soil exhaustion, leading to the eventual collapse and dying back of the cabbage, or else "sporadic bud-rot," where the disease is usually secondary to injuries of various types.

COCO-NUT ROOT DISEASES.

Bryce, 1924[14] described a root disease of coco-nuts due to *Fomes lucidus* (Leys) (*Ganoderma lucidum*), first described by Petch in 1910 and recorded by the author from Walis Island, off the New Guinea coast. The fungus, however, was first recorded by Schumann and Lauterbach on Bougainville Island and on the mainland. This disease has been found in Java on dry sandy loams and in Malaya is said sometimes to attack the roots of backward palms. It has been proved experimentally that the parasitism of *Ganoderma lucidum* is very low.[81]

In another leaflet[15] he described root diseases caused by *Fomes lignosus* Klotzch (now known as *Rigidoporus microporus*) and *Fomes Lamoensis* murr (true name = *F. Noxious*). The former was recorded earlier by German investigators, and also in Dutch New Guinea. These leaflets are available from this Department of Agriculture, hence it is not proposed to deal with the descriptions further. It is intended to present the author's opinion of the status of coco-nut root diseases in New Guinea.

From experience gained to date, one is inclined to agree with Park[51] and Sharples[61] in their conclusions that root diseases of coco-nuts are not such important causes of loss of coco-nuts as was formerly believed, in any case, as far as New Guinea is concerned. Park states[51] that the coco-nut palm does not appear to succumb readily to the attacks of root fungi, and it is unusual to find what may be termed spectacular instances of death by root disease. Muller[44] stated personally that extensive areas of coco-nut palms in Western Borneo, where the water table was too high, were found attacked by *Polyporus spp.* &c., and 50,000 palms died, and that root rots were mainly found where soil conditions are not suited to coco-nuts.

It is said in the Philippines that root diseases are common in water-logged soils, but that the primary cause of rotting may be due to lack of root aeration.

Sharples[61] goes so far as to state that little definite root disease of coco-nuts has been found in Malaya, and that other causes are usually responsible for the death of coco-nut palms.

It appears that the presence of numerous root-rotting fungi has been conspicuous on bases of ordinary trees in the tropics, e.g., the species of Fomes which have been found on coco-nuts have been recorded on several other hosts of plants. Their presence on avenue trees, such as *Poinciana regia* and Peltophorum, in Rabaul, is sufficient to show their effect on susceptible trees under tropical conditions.

Nevertheless, coco-nuts have a different root system from the ordinary trees found in the tropics, even including such crops as cocoa, rubber and coffee. These latter belong to the great group of dicotyledons, while the coco-nut is a monocotyledon. This does not imply that monocotyledons are resistant to root diseases, as maize, which is a monocotyledon, is very liable to root-rotting. It does indicate, however, that palms do not form a tap root, and that they produce their roots in succession throughout life from the base of the stem. In the case of coco-nuts, these main roots are very uniform in size, and are provided with a hard, lignified, shell-like epidermis or skin. The main roots may branch to form other straight-growing roots, but from these arise small branching roots,

which are the feeding roots of the palm. Thus, if a root of a palm is damaged so that the rootlets die, these will either be replaced near the tip or a new root will form at the base of the palm.

Park[53] states that this faculty for replacing injured or diseased roots is of importance in disease of coco-nuts, since so long as the pathogen (fungus, &c.) confines itself to the roots, it is possible for the palm to go on replacing affected roots, provided that the environmental conditions are favorable for its growth.

It is conceivable that a fungus which could be definitely parasitic on the base of the palm would be more likely to cause the death of the coco-nut. This type of infection apparently is of rather rare occurrence, and might only be brought on where other fungi or unfavorable soil conditions have caused the death of the feeding rootlets and reduced the vigour of the palm.

General Description of Root Disease.

The following typical description of the condition of coco-nut palms affected by root disease is generally presented.

The outer leaves of palms affected wither and hang drooping downwards around the stem. The central upright leaves and the unfolded sword-like leaf remain green and of full size. A few green half-ripe nuts may remain on the palm, while the bud is quite sound. Later the outer drooping leaves fall away, leaving a cluster of upright leaves at the top of the stem. This condition may persist for some years; the new leaves formed being successively smaller until at last they will wither away and the bud decays. The palm in this condition does not set any nuts, and later ceases to produce spathes or flowering branches. It is hardly necessary to point out that this description fits in accurately with what occurs under conditions of soil deficiency, causing dying back and incipient chlorosis of the coco-nut palm.

Suspected Coco-nut Root Diseases.

A suspected case of root disease was reported from the Mortlock Islands in 1933 by Crocker, inspector and instructor of this Department.

The first indication of the disease was the falling of all fruit, while the fronds broke and about half-way from the base were seen to hang over. The fronds then died back, and finally the complete cabbages fell over and the palms died. The appearance of an attacked palm was similar to one which has been struck by lightning, except that the external markings and burns usually associated with lightning were not present. Moreover, this disease kills single palms frequently, and not always a group of palms, as occurs in the immediate vicinity of a lightning-struck palm.

Affected palms felled for examination showed no signs of insect attack; the cabbage in every case was clean, and no unusual smell was noticed. The trunks or palm stems showed no external signs, but the pith in the centre of each was discoloured a brownish red. The affected area composed one-third of the diameter and extended from the base throughout the entire length of the trunk. This discoloured portion was surrounded by apparently healthy palm tissue.

The natives at the Mortlock Islands state that they have removed more than 200 palms killed by this disease, and during the inspection quite 100 dying and

dead palms were noticed. The disease appears to be confined to one island of the group which is the largest and lies on the southern side of the atoll. The disease was referred to in the report as "coco-nut root disease." The Mortlock Islands are coral islands with a fringe of raised ground, but are usually low-lying in the centre, where the ground is swampy and heavy. It is a pity that the brownish-red discolouration was not examined microscopically for any presence of eelworms or fungus. Such soil conditions, however, are unsuitable for healthy growth of coco-nuts, and would be sufficient to cause the death of the palms.

In 1933 the following inquiry was received from the Manager of a plantation situated on the south coast of New Britain. On the plantation there was a batch of about fifteen palms which appeared to be making no headway. These palms were about eighteen years old, and about 4 feet of the stem below the crown showed a marked diminution in diameter. The fronds were few and yellow, although the spikes were alive and growing. There were no signs of nuts or spathes. In comparison with the rest of the plantation the grass was growing poorly, but the species present formed a dense mat.

The present Director, in answer to this inquiry, remarked that the marked diminution in the diameter of the trunk clearly indicated that the palms were in extremely poor health. If the land is swampy it should be drained, and, in any case, if the palms are not too far gone, they should benefit by cultivation and the use of cover plants (Calopogonuim, &c.), or erect green manure plants such as Crotalaria or Tephrosia.

Earle[26] described a condition from Jamaica under the heading "Coco-nut Wasting Disease," in which the symptoms were as follow: "The nuts fall a few at a time; the lower leaves droop and fall prematurely, while the new leaves that are produced become successively smaller and less vigorous. In the final stage the leaves are reduced to less than half the normal size, and the few that remain stand erect as a thin wisp at the apex of the bare stem. In the trees examined a white scale was always found at the base of the petiole (leaf stalk) and on the fruiting peduncles, but they were also seen on palms not showing recognizable symptoms of the disease.

Furtado[28] states that most of the tapering trees he had seen in Akyab, Burma, were in underdrained and neglected situations subject to heavy floods in the rainy season. The longest leaves measured on many palms were not more than 1½ yards in length. There was no sign of any organism doing damage to the aerial parts of the trees.

De Mel,[43] writing on the occurrence of "Tapering Disease" in the North-west Provinces, Ceylon, states that the disease is important there. It was found that a large number of healthy palms which had been good bearers showed a gradual tapering of the uppermost part of the trunk, which proceeded in spite of manuring and good cultivation. The fronds next began to decrease in size and became fewer in number, while the yield fell off entirely. The leaves gradually turned a greenish yellow, and in the final stages the number of branches was reduced to seven or less. The tapering had meanwhile proceeded so far that the slender trunk could no longer support the fronds, which then fell off altogether.

At this stage the bud-tissue often would be found rotting, but this was quite distinct from true bud-rot. The period that elapsed from the first signs of tapering to the death of the tree was from two to three years.

There is a second type of diseased tree, equally well distributed in Ceylon, in which no signs of tapering were evident. The first symptom is a faint yellowing of the uppermost fronds. The fronds become gradually less in number and smaller in size, and soon the tree ceases to bear. Trees in both these types of disease range in age from 20-40 years, and have in most cases been good bearers of healthy growth and in all respects normal.

The above or similar symptoms can be expected from a variety of causes, such as malnutrition, rock pan and impervious clay bottom and water-logging conditions; in the last case a very distinct yellowing of the leaves results. It is not unusual to see stunted and tapering trees on neglected lands, but the diseased trees described were found in good soil and situation, on well-cultivated estates, where other possible unfavorable causes were eliminated. This suggested the possibility of root diseases being present.

TAPERING STEM, ASSOCIATED WITH SOIL EROSION.

Evidence of root disease in India was first described by Petch, when he recognized *Fomes lucidus* in a section of a diseased bole of a coco-nut tree. The following seven fungi have been found associated with root diseases in India:—[43] *Diplodia, Poria,* three species of *Fomes, Polyporus Zonalis,* and later *Rhizoctonia bataticola.*

Huggins[85] described "bronze leaf wilt" of coco-nuts in British Guiana as a result of planting on unsuitable land in the first instance, and subsequent neglect. Large numbers of coco-nut trees in the colony are lost from wilt disease (formerly known as bud-rot), a condition primarily brought about by unfavorable environmental conditions, and entirely comparable in cause and effect with the "bronze leaf wilt" of coco-nuts in Trinidad (*see* Briton Jones,[9] also Bain[7]). Contributory factors to the occurrence of the disease are insufficient nutrient supply, water-logging and poor cultivation in general, the latter resulting in a

bad condition of the soil and an overgrowth of weeds, which block the drains and compete with the palms, to the disadvantage of the latter. The disease is most usually found upon heavy soils, but occasionally appears on sand reefs. The symptoms exhibited by the palms are a yellowing, and later bronzing, in colour of the leaves, which eventually die and hang down. The outer (i.e., the oldest) leaves are affected first, and then the other leaves follow in succession, the crown of the palm being the last part to lose its green colour. By the time half to two-thirds of the leaves have died, however, the heart and bud of the tree become involved in a wet foetid rot, which is very evident if an affected palm be felled and the crown opened longitudinally. The organisms which cause this rot are only secondary factors, and only attack the already weakened tissues.

Park in 1927[50] discovered *Rhizoctonia bataticola* (Taub) Butler in association with root disease of coco-nuts in Ceylon. The symptoms of the disease of the young palms were a yellowing and subsequent death of the outer leaves, which progressed inwards; dwarfing of the young central leaves, and in extreme cases a rotting of the central bud followed. He found this fungus on the dead roots of coco-nut palms displaying symptoms of tapering in a number of districts in Ceylon. It was suggested, however, that the fungus was probably normally associated with healthy roots (mycorrhizal) and many only produce sclerotia (reproductive bodies) when some conditions arise to cause the death of the roots.

Small, 1927,[68–69–70] noted the occurrence of this fungus on numerous species of plants and was led to believe that *Rhizoctonia bataticola* was the basic cause of root disease on many plants in Ceylon. He expressed some doubt as to the primary parasitism of fungi usually thought to cause root disease such as *Fomes spp., Ustilinia, Poria,* &c., and suggested that these may hasten the harmful work begun by *Rhizoctonia* and lead to a more rapid death. This has led to a wide controversy as to the actual causal agents of root diseases.

Gadd[32] and Briton Jones[10-11-12] are not inclined to accept Small's views as to the immediate responsibility of this fungus for root diseases of cultivated plants. It has been shown in some cases the fungus follows a check to the host plant due to physiological and other causes, hence the question demands further investigation.

Briton Jones, although stating that it requires special conditions to induce *Rhizoctonia* to cause root-rot, expressed the view, however, that this parasite is the real cause of diseases hitherto attributed to fungi such as *Polyporus microporus* Schw. Fr. = *Fomes lignosus* Klotsch, is correct. He stated that in Trinidad this latter fungus is common on stumps in cacao plantations, but it has never been recorded as causing root diseases in that island.

Petch[54] states that the behaviour of *"Fomes lignosus"* on cacao in the West Indies is evidently quite different from that in Ceylon. One in Ceylon was indicated where in a mixed estate of cacao, rubber and coco-nuts, a rubber tree at the head of a small valley was attacked by *Fomes lignosus* and died; no treatment was applied and the fungus mycelium spread down the valley killing all the cacao and coco-nuts in its path. He maintains that this is another fungus altogether, and that the correct name of the fungus, called *Fomes lignosus* in the East Indies, is not known.

The fungus known as *Fomes lignosus* in the West Indies is identical with *Polyporus microporus* (S.W.) Fr., the latter name having priority over the former,

which should be discarded as a synonym. Since Petch made the above statement, the fungus called *Fomes lignosus* in the east has been identified as *Rigidoporus microporus* (Swartz) van Overeem.

This controversy is quoted to show that the true status of the fungus causing root diseases in plants has not yet been adequately determined. It is thought fit to indicate, however, that the author has recently collected *Rhizoctonia bataticola* on sweet potatoes, *Ipomea batatus,* at Keravat Demonstration Plantation, New Britain, and has also recorded the same fungus on coffee. So far no work has been done to determine whether this fungus is present on coco-nut roots.

Rhizoctonia bataticola is widely spread in both the eastern and western tropics and attacks probably 30 species of plants, but probably only causes damage under unfavorable environmental conditions.

THE RELATION OF SOIL CONDITIONS TO DISEASE OCCURRENCE.

The occurrence of "bronze leaf wilt" in Trinidad has already been mentioned in the discussion of bud-rot. Briton Jones[9] expressed the opinion, based on his observations in Trinidad and some of the other West Indian islands, "that the onset of 'bronze leaf wilt' is in the majority of cases due to physiological drought which does not need a prolonged period, but may become evident after a short dry period under certain soil conditions, especially where the soil is heavy and in bad tilth." Bronze leaf symptoms were experimentally reproduced in healthy palms by digging trenches around them.

The soils on which the disease is serious were said to be generally heavy, in very bad tilth and constitutionally such that they do not draw well but dry out rapidly and crack in the dry season. The very definite correlation between lack of drainage and the incidence of the disease indicated that any organism present was a secondary factor, and the primary cause is suggested very strongly as a soil factor.

The general wilting of coco-nut palms often seen after a long spell of dry weather in portions of New Guinea (e.g., the Gazelle Peninsula), with usually a subsequent recovery when the rains occur, shows some features in common with the above occurrences. It is, however, usually seen on light, porous soils with poor water-holding capacity. The lower leaves do brown off and wither, but these palms immediately respond to good rains.

Park[53] refers to the effects of "drought" on coco-nuts in Ceylon. He first suspected bud-rot infestation as one estate of 100 acres contained 600 dead or dying palms. The standard of cultivation on the estate was poor and it was found that the condition was due to the effects of drought, while the buds fell off from mechanical causes only. The brown discolouration of the older leaves did not appear to be due to the parasitic action of a fungus. He stated that the condition was comparable with "bronze leaf wilt" disease recorded by Briton Jones in Trinidad.[9] The condition was worst on low-lying land liable to water-logging in wet weather, due to the effects of this water-logging on the root system of the plant. Here the palms were shallow rooting and first to suffer the effects of drought. The effects of good cultivation were marked under these conditions and drainage to induce deep rooting was advocated, as was cultivating and removal of the dead palms.

Park[51] also recorded root diseases causing rotting of the central bud, followed by death of the palms, where the soil conditions were poor, being of a very sandy, dry nature and with brackish water in the vicinity.

In referring to root-rots caused by *Fomes lucidus,* he thought it possible that attacks by this fungus near the collar are induced by certain conditions of the soil, since the fungus is common in coco-nut land, whereas the disease caused by it is rare.

Dowson[25] mentions the development of bud-rotted palms in Mombasa, East Africa, where the cultivation of the palms was poor and they were growing in rank grass and weeds. He saw areas without palms which the local natives asserted would not grow coco-nuts at all despite repeated trials and some of these areas were certainly swampy. Bud-rot had never been observed in more vigorous palms around the houses and in the native encampment.

Alston[1], writing on coco-nuts in British Guiana, stated that the condition known as bud-rot (now called wilt) in that country is evidently not induced by the operations of any specific organism, but is primarily to be attributed to unfavorable soil conditions, whose deleterious effects have in many instances been aggravated by cultural neglect. The cultivations which were the more severely affected are those situated either on low-lying, badly-drained, heavy, clay front lands, or on pegass soils which suffer from similar disabilities. Except for occasional weeding, the cultivation had been neglected from a very early period in the life of the trees.

Sharples[61] states "that in cases such as those quoted the question of specific palm diseases seems to have been given undue prominence."

"In many cases it is obvious that the improvement of bad cultural conditions is of greater importance than the question of the cause and prevention of specific diseases."

It appears, however, that a number of specific fungi are always present, if not on the coco-nuts, on alternate plants. If, by any cause whatsoever, the vitality of the palm is lowered, e.g., genetical or hereditary weaknesses, weakness due to insect attack, bad cultural conditions, presence of injurious grasses and weeds, drought conditions, heavy or poor soils with bad drainage, there is a decided pre-disposition to attack by fungi which otherwise would be only weakly parasitic. There are few plantations on which in some areas such pre-disposing causes are not found at some time or another.

From the viewpoint of the practical planter here, which is not concerned with long lists of scientific names suspected of causing root rot, it is doubtful whether any serious disease which is not associated with unfavorable soil conditions has been found in New Guinea.

It is certain that no epidemics of root disease have been reported and where suspected, have usually been found associated with low-lying, heavy soils, or where soil deficiency and chlorosis were in evidence. It is shown that, under favorable conditions, the coco-nut has, apparently, very good resistance to root diseases owing to the nature and structure of the roots.

It would be too much to say that root rotting of coco-nut palms does not occur here and further investigation as to what fungi may be associated with the dying back of coco-nut palms on unfavorable areas is required. There is, however, more decided room for investigations as to what conditions, particularly soil conditions, are injurious or beneficial to the palm. It is a definite fact that root

rotting is not likely to be serious here where the vigour and health of the palms is maintained. In the author's opinion a number of the so-called bad cases of root rots can be ascribed to chlorotic deficiency diseases, a fact which has already been proved in the case of coffee[8].

DEFICIENCY DISEASES.

The "Chlorosis" and "die back" deficiency diseases are recognized as serious diseases in coffee cultivation. Nowhere are physiological diseases due to manurial deficiencies so evident as in the tropics, for the obvious reason that excessive rainfall causes increased leaching which greatly reduces the humus and mineral salts content of the soils.

TAPERING STEM AND REDUCED LEAF AREA DUE TO SOIL DEFICIENCY.

TAPERING STEM AND REDUCED LEAF AREA DUE TO SOIL DEFICIENCY.

Beckley[8] states that in Kenya, Africa, whole coffee plantations may become chlorotic, showing up as yellow patches in the landscape. He recognizes at least two main types of chlorosis. One form is ascribed to an inadequate supply of nitrogen at the period of maximum demand. It is usually accompanied by die-back and involves severe loss of crop. Another form very similar in appearance is

attributed to a deficient carbohydrate supply and is accompanied by severe die back both of branches and roots. It is believed that deficiency diseases similar to those cited in this article are present in coco-nut plantations.

Reference to a previous article (*New Guinea Agricultural Gazette,* vol. 2, No. 2) which refers to the condition of the planted areas in New Guinea indicates that, in some of the plantings made in 1918, fields of young coco-nuts were planted in stagnant swamps which could never be of any value. Many areas are planted on soils and in positions quite unsuitable for coco-nuts, e.g., badly drained clay soils or on poor sandy areas. The amount of fertilizing material removed from this country each year without any attempt at replacement amounts to several thousand tons per annum.

The older planted areas in scattered parts of this country are definitely beyond their stage of maximum production, with the result that the output of such old plantations is rapidly decreasing. In many areas where copra has been produced for a considerable number of years there is decided evidence of soil exhaustion due to manurial deficiencies. It is impossible to continue exhausting all the manurial constituents from the soil over a period of years, especially where decayed vegetable matter or humus is burned out of the soil, due to lack of overhead shade, without undesirable results.

Lever 1934[39-40] referring to the British Solomon Islands stated "Soils such as are not uncommon in the Protectorate have by repeated cropping had their available reserves reduced to a minimum for plant growth and are said to be exhausted. The continued growth of almost any crop leads to exhaustion, so that measures must be taken from time to time to compensate the soil for the repeated losses which it has sustained."

It is time that some provision was being made to remedy this position by the most economical methods, e.g., by growing green manure crops or applying artificial fertilizers, and experimentation is necessary to determine the best ways and means of doing this.

It appears that chlorotic diseases (N.B., Chlorosis has reference to absence of green colouring matter and reduction of leaf absorbing surface) associated with soil deficiency are very important in this country, especially on old plantations where the soils are not particularly rich.

It is invariably noticed that where the vitality of the palms is reduced by soil exhaustion, lack of drainage, poor cultural methods, drought, insect attack, &c., fungus diseases which are normally weakly parasitic, such as *Pestalozzia palmivora, Helminthosporium spp.*, and others, gain the ascendancy and, besides reducing the yield, badly affect the palms.

Simmonds in 1924[66-67] also made the following comments regarding a number of old-established coco-nut plantations at Kokopo and the north coast of New Britain:—"The soil here is all pumice and very poor, the trees, which are mostly about 30 years old, showing much yellowness, giving every indication of considerable soil exhaustion (= chlorosis). A coarse grass locally called Kunai or Lalang grew everywhere, causing much trouble and doubtless still further reducing the yield of nuts".

The author has seen a number of areas in the east and west coast of New Ireland, Kavieng district, which are non-bearing areas, where low-lying, heavy

clay soils exist. These are badly drained, often water-logged and entirely unsuited to coco-nuts. On the west coast at varying distances from the shore is a decided strip of heavy clay country which extends right to the foothills. Chemical analysis has proved this soil to be low in lime and potash. Palms planted on this country remain dwarfed, appear yellowish and will not bear nuts or thrive. The foreshore areas and lighter soils bear very good coconuts and the trees are healthy and vigorous. It would be a distinct boon to planters, especially with limited foreshore areas, to find that coffee, cocoa, or other profitable crops would succeed on these heavy soils, hence experimentation is necessary.

It must not be thought that this condition is confined to New Ireland, as the soils in parts of New Hanover and the outlying areas are so clayey that coco-nuts succeed but poorly. Similar conditions have been observed in Bougainville Islands and in most areas visited, and is common on the older planted areas of the mainland. In the western islands the soils are usually rather shallow and light, being of coral derivation. Here the palms mature early and prosper for some years but gradually go off as the soil constituents become exhausted. The stems commence to show all the signs of a deficiency disease, the stems taper, the leaves become gradually smaller and fewer, and at last the tops fall off, giving all the appearance of a bud-rot condition. A coral hard-pan too near the surface is undesirable for coco-nuts as, besides checking root growth, it retains the rain water after heavy falls, and so tends to make the soil water-logged, to the detriment of the roots.

It seems superfluous to describe the appearance of palms on the soil exhausted areas in New Guinea. Such palms appear a sickly yellowish green in colour, the fronds present a feathery and very unhealthy chlorotic appearance. As the fronds reduce in size and number so the overhead canopy and shade diminishes, which present excellent conditions for the ubiquitous Kunai grass (*Imperata arundinacea*), which thrives in open sunlight. The spread of this grass with its very matted root system, together with the fact that the humus and other constituents are readily burnt and leached out of the soil under such conditions, produces severe cumulative and adverse effects on the palm itself. In advanced stages the tips of the fronds wither and this gradually extends to the base until the dead leaves, although remaining attached to the palm, hang down and are wrapped around the trunk until they eventually fall. The stems usually show marked tapering, probably coincident with the period where soil exhaustion and the environment became unfavorable.

In the late stages the top falls over, leaving just the bare trunk, which provides a harbour for beetles, &c., and, although arising from a different cause, has many of the appearances of a bud-rotted palm. In such cases, however, the decline commences from the outside inwards and is a very gradual process. In many instances such palms are found in distinct belts where light pumice soils exist, while in some cases the areas were said to be covered with Kunai before the palms were planted. The question of whether rehabilitation of such areas is an economic proposition is a very vexed one which will be dealt with in later articles. It is pointed out that on such areas the production is low, few spathes, if any, are produced in the worst instances, and many palms are totally non-bearing, while the relationship of poor soil conditions to the nutfall problem is described elsewhere.

SOFT LEATHERY KERNEL OF COCONUTS.

On certain plantations in the Bismark Archipelago defective coco-nuts showing a thin, leathery, soft kernel are produced. When such green copra is cut and dried in the normal manner it does not dry out properly, but remains soft, flexible and leathery, often becomes brown in colour and is of poor appearance and quality. This condition is not due to defective drying, and it has been found that the palms which produce such copra are confined to certain areas on the plantation.

It has been seen by the author that the kernel produced on soil exhausted areas, such as on some of the islands near New Ireland, becomes thinner as the plantations commence to show signs of soil exhaustion. It might be that certain palms show an hereditary tendency to produce such soft kernel, but the fact that the condition is confined to certain areas points to the fact that soil impoverishment or lack of certain essential elements in the soil is the cause of the condition.

It is well known that coco-nuts which have germinated produce a soft and rather thin copra, but this is distinct from the condition mentioned above. Investigation of the cause of this defect is largely a matter for the chemist.

RECENT OCCURRENCE OF AN OBSCURE PHYSIOLOGICAL CONDITION IN NEW IRELAND.

The palms on the plantation where this condition was recorded range from five to eight years old and, in most instances, had just commenced to come into bearing. The general condition of the palms in the areas affected did not appear so good as in the surrounding areas. The trouble was only found in areas well away from the beach where the palms were planted at the wide spacings of 33 feet and 36 feet on the triangle system. The main area which was affected was situated in a hollow depression and comprised a total of about 600 palms, and numerous palms scattered over this area showed symptoms as described. There were a couple of other widely separated areas which showed the condition.

Pronounced tip withering occurred on the centre leaves of the affected palms, and some dying back was also seen on the outer leaves. On the back of the petioles (leaf stalks) of the crown leaves of the palms, pale brown streaks were seen. These sometimes showed up near the tip of the leaf or near the base, but as a general rule commenced about two-thirds of the way up from the base. The scattered areas, although moist in appearance, were quite firm, but later they tended to spread and link up, becoming sunken below the general level of the outer surface of the midrib. Eventually the diseased area split longitudinally, exposing the fibres after the ground tissues had fallen away, and the unhealthy areas become quite dry and hard.

A cross section made after drying out had occurred showed a pale sulphur yellow layer immediately underneath the sunken tissue; this merged into a brown discolouration extending through the petiole almost to the inner surface. In longitudinal section the discoloured area showed up as dull reddish brown streaks. Such rotted areas were seen in some cases to extend below the fibrous tissue at the base of the leaves, but in no case did it appear to kill the palms. A tip wither of the leaflets which extended from the top of the fronds almost to the base generally occurred concurrently with the stem rotting mentioned.

Around the edges of the withered areas on the leaflets a distinct halo was noticed in some cases and the die back from the tips was very distinctive. Pale areas with brown margins also appeared in the centre of the leaflets. The above symptoms only showed up on the fronds comprising the crown, while the older leaves were usually not affected.

It appeared that the palms affected were tall, very erect and close-growing, and not an open, robust type. They often presented a frond-choked appearance with the fibrous tissue bound tightly round the bases of the fronds. The only palms affected were those bearing nuts or flowering before coming into bearing. The nuts from diseased palms showed an unhealthy yellow colour. Examination of the roots showed no evidence of root disease.

The land prior to planting was under fairly heavy secondary growth and in the past had been used as native gardens. The land is undulating and rises gently from the beach. The soil on the beach and ridges is shallow and overlies coraline limestone. On the slopes and in the depressions the soil was much deeper and in places reached a depth of about 4 feet. In the profile the soil on the slopes showed a medium dark red friable loam at the surface, which rapidly merged into a red or chocolate rather stiff clayey subsoil. A heavy growth of weeds and shrubs was allowed to grow over the area and amongst these Thurston grass, *Paspalum conjugatum,* and Kunai, *Imperata arundinacea,* were seen on the affected areas.

The fungus *Pestalozzia palmarum* or Grey Blight and the insect *Brontispa Froggati* were scattered widely in the plantation. The diseased palms seemed to be more plentiful where a heavy infestation of white fly, *Aleurodicus destructor,* and other unidentified scales were present. These were more plentiful in the hollows than on the ridges. Microscopical examination of diseased specimens failed to show any strongly parasitic organisms, although it did yield some interesting technical results.

Detailed investigations by the author and Henderson led to the conclusion that the condition was local and of physiological origin. One interesting feature concerning the topography was the presence of several large holes or depressions such as are often seen in country of coral origin. These extended well down into the underlying coral and in one case a stream of water was running at the bottom of the declivity. It is believed that there is a subterranean passage and a large underground water channel underneath the area where the palms were affected. Here the rain water readily penetrated to the lower layers and was quickly carried away.

It appeared also that the roots of the palms showing the upright frond-choked condition had only penetrated the upper and more friable layers of soil while the roots of the stronger palms had penetrated deeper into the subsoil. Practically all of the affected palms when pushed strongly could be rocked backwards and forwards, showing that the rooting was shallow and that this type of palm had a loose hold on the soil. The root hold had been further reduced by the doubtful expedient of digging in deeply around the palms so that many of the surface roots were cut. Whether this was also affected by original shallow planting in the first instance was not known, but appears likely. The appearance of the disease was associated with a pronounced spell of dry weather following on relatively heavy rains. It occurred, however, where the soil was apparently well suited to coco-nuts, although a little heavy in the subsoil. The rainfall for the

months of April, May, June and July, 1936, i.e., preceding the appearance of the disease, was just about half the average for those months at the nearest recording station, but the rainfall was said to be much lower than this at the plantation in question.

The malady made an appearance when the palms were coming into bearing, which is a critical period in the life of the palm, when an additional strain is caused by additional water and nutritional requirements.

During the dry period shallow-rooting, rather weak palms were not able to obtain sufficient water and plant food to carry on normally, especially where the water could get away so easily. Further, insect attack and probably the effect of weakly parasitic fungi had some effect when the vitality of these palms was lowered and this caused some of the withering seen on the central leaves.

It is a significant fact that recovery was coincident with the proper cleaning up of the place by cutting down high brush weeds, &c., and more particularly with the incidence of abundant rainfall. The white flies and various scale insects were very much less in evidence after the plantation was cleaned up and the rain occurred, which probably had some effect on the recovery of the palms.

The owner of this plantation became very concerned and drastically cut back many palms, in some cases leaving only the central shoot, which led to a bud-rotting condition, which was probably associated with the entrance of secondary fungi and bacteria. Where the palms were cut back judiciously at a later interval and not too many fronds removed they made a good recovery.

Technical Discussion.

Plate and slope cultures of the organisms present were made. Diplodia-like spores associated with a sickle-shaped Fusarium spores were present and it might be stated that this association has been seen in several instances here.

Wollenweber[82] in the text book of Soraeur[72] depicts the relationship between such spore stages, and perfect stages such as Nectria and Sphaerostilbe, which are sometimes regarded as of little importance. Thus it seems that the true identification of the Fusaria or Diplodia here is wanted before it can be stated definitely whether these fungi would be of any primary importance. It appeared, however, to be secondary in this case and inoculation experiments on young palms yielded no results.

A species of eelworm, however, was found, associated with diseased tissue on the leaf stalks. It was not plentiful but seemed to conform somewhat with the description of *Patho-aphelencus* which is known to cause red ring disease in the West Indies.[3–46] No red ring disease has been noticed on the affected palms, hence this is probably a saprophytic strain of no importance. Specimens are prepared and will be sent to the Imperial Bureau of Parasitology for proper identification.

Henderson, Inspector and Instructor, was unable to locate further eelworms in the affected tissues, hence they were not plentiful.

This is absolutely the first record, however, of eelworms being found on the aerial portions of coco-nut palms in New Guinea, and this is of technical importance only. Further, on all the cultures made, a very short bacteria (almost a micrococcus) was found which formed whitish colonies later turning pink on the agar. It formed a zooqloea and did not infect the wounded leaves of very young palms.

NUT-FALL IN COCO-NUTS.

Investigations in other Countries.

Petch[84] records that after the heavy and unseasonable rains of January and February, 1917, in Ceylon, an extensive fall of nearly mature nuts occurred on some estates, and on one estate of about 600 acres over 100,000 immature fallen nuts were collected in the month of March. He continued by stating that the fall of immature nuts in their earliest stages, when they are about 2 inches long, is a well known and common event. Numbers of such small fruits drop off a month or two after the flower has opened; and it is generally supposed that more fall off in the dry weather than in the wet season. It is probable that, in many cases, such fruits have not been fertilized. The nuts which fell off, in the cases referred to, were from half to two-thirds grown or in some cases they had reached their full size but were not ripe enough to be of any use.

SPECIMEN FROM NUT-FALL AREA, MAINLAND OF NEW GUINEA.
N.B.—Surface lesions and varying sizes of coco-nuts.

When the fallen nuts were examined soon after they had fallen the stalk-end of the nut was found to be diseased and discoloured, and generally there was a dark brown or blackish-brown patch extending from the scar downwards, over the surface of the fruit. When the nut was cut open the diseased discoloured region was found to spread downwards into the husk. The fungus which caused this disease was identified as *Phytophora spp.*, which is always worst in wet seasons because the fungus requires an abundance of moisture for the development of its spores. He described "Leaf Droop" as an associated disease caused by the same fungus.

Stockdale[76] briefly describes the same diseases from the Kurunegala District, Ceylon, where the rainfall was said to be rather excessive for optimum growth of coco-nuts, and the soils heavy. It was only under these conditions that leaf-droop and nut-fall proved serious, in Ceylon, and under excessive and continuous

spells of wet weather proved capable of considerable damage to palms and crops even in well-cultivated plantations. In some cases the nut-fall was considerable, especially where continuous light or misty rains occurred on a number of days. In isolated cases vigorously growing palms dropped 50 per. cent. of their nut crop—the nuts being all sizes, but usually about half-grown.

He suggested the following remedies for these diseases:—

Good cultivation, better drainage, regular collection and destruction of all fallen, diseased nuts and diseased leaves; spraying palms as a preventive measure, but indicated that only under some circumstances would it pay.

Teodoro[77] states that immature nut-fall in the Phillipines was due in some cases to the fruit flowers not being fertilized, but in the majority of cases was caused by a fungus (*Phytopthora spp.*) which grows on the base of the nuts. This fungus may be detected by the presence of a dark brown or blackish brown patch at the button end of the nut which often spreads half way up the base of the nut. The disease was most serious in wet seasons. Nut-fall due to *Phytopthora* has not yet been recorded in New Guinea, though there is some chance that further investigation may reveal its presence here.

Gadd in 1923[32] stated that the fall of nearly full grown but immature nuts was formerly regarded as being primarily due to fungus attacks (e.g., *Phytophora*). Nevertheless a causative organism was not always associated with the disease which led to the contention that mechanical, adverse, physiological or environmental conditions may be responsible in some cases. He reported a serious case of fruit fall in coco-nuts from Indo-China in 1920, which after comparative analyses of the soils led to the conclusion that the fundamental cause was insufficient nitrogen which was remedied by the application of nitrogenous manures.

In Ceylon it was shown that water deficit, following on a prolonged drought, caused greatly increased fall of the "female flowers" or "button nuts". Such a fall of buttons was previously attributed mainly to lack of fertilization, but abscission of youngest fruits may be caused by periods of drought which may also lead to the abscission (falling) of larger nuts.

He indicates, however, that nut-fall in Ceylon occurs principally in the rainy season, and in the districts where it was particularly severe the soils were heavy loams which become hard during dry weather, with a tendency to water-logging during heavy rains. These soil conditions, during heavy rains, become deleterious to the healthy growth of the root system by interfering with the air supply which, despite the excess of moisture present leads to reduced absorption of water, and untimely death of the roots—resulting in nut-fall.

Cook, Porto Rico, 1925[23], described the premature dropping of nuts in various stages of growth from the very smallest up to those that were practically mature, all of which showed a black discolouration at the base. In some cases this blackened area became dry after the dropping of the nuts while in other cases it developed into a soft rot. The disease was more prevalent in some areas near the coast where moisture and litter were abundant and was worst on low palms. Examination and controlled inoculation experiments proved without doubt that the cause of these occurrences was *Thielaviopsis paradoxa*, the organism which

is also responsible for "stem bleeding" disease, known to be present in New Guinea. Successful control was obtained by a very general cleaning-up of all litter on plantations, and the removal of diseased leaves and nuts as far as possible.

Ashby[5] states that the first indication of one form of bud-rot in Cuba and the West Indies is shedding of young nuts, followed by dark discolouration of successive flower spikes as they emerge from the swords.

Nut-Fall in the British Solomon Islands.

In 1911, Froggatt, W. W.,[29] mentioned that a planter from Gizo, British Solomons, had informed him that the bug, *Axiagastus cambelli,* was causing immature nut-fall in his plantation.

Simmonds, 1923[66-67] noticed the very variable but poor yields of coco-nuts in portion of Gaudalcanal, British Solomon Islands. Premature nut-fall was noticed and both *Tirathaba rufivena* and *Axiagastus cambelli* were recorded as pests on coco-nut spathes both in New Guinea and the B.S.I.P.

Tothill and Paine, 1928[79] mentioned *Axiagastus cambelli,* the coco-nut flower bug, as a cause of nut-fall in the Solomons.

Prior to 1934, the investigators in the British Solomons were inclined to the view that soil conditions were responsible for nut-fall, or else unfavorable soil conditions, and variable rainfall combined were interacting causes.

Lever[36] 1933 sent four samples of soil from Malaita Island from a block yielding very poor crops of coco-nuts to the Imperial Institute for analysis. It was pointed out that the samples of soil and subsoil were of an extremely heavy character.

The report on the analyses[36] showed that from a chemical point of view the particular soils were poor. The amounts of acid-soluble lime were low, especially for heavy soils, being exceeded slightly by those of magnesia, a condition which is often regarded as indicating poor fertility. The percentages of acid soluble potash and phosphoric acid were low, and very little of the latter was present in available form. It appeared quite likely that this lateritic clay soil would become water-logged under a heavy rainfall and would be unlikely to repay artificial manuring.

It is assumed, however, that these soils were derived from an area which was not typical of the Solomon Islands coco-nut soils.

In 1934 a report was received from London concerning the soils at Lunga, B.S.I. According to the investigators the differences in samples of soils taken from good and bad nut-fall areas were not sufficient to cause the enormous differences in fertility. Phillips stated personally that the foliage and general appearance of the nut-fall palms were healthy, and it was considered that unsuitable soil conditions would affect the foliage.

It is understood that nut-fall is a far more serious problem in several large areas of the British Solomons than it is in the Mandated Territory of New Guinea. Hence deservedly it has received more attention in the B.S.I.P. Lever[41] and Lever and Phillips[42] have published articles on the subject. It is known that a soil chemist has recently been appointed to study soil conditions there. Messrs. Levers Pacific Plantations Limited and the Agricultural Committee of the British Solomon Islands in co-operation are mainly responsible for initiating this work.

The possibility of fungus infection is not being overlooked by the investigators. Any results achieved so close at hand will be of considerable interest to New Guinea, hence a brief *résumé* of their findings to date is given, which it must be admitted have been more the province of the entomologist. According to recent findings of the Director of the Imperial Mycological Institute, from specimens submitted, it does not seem that the falling of young nuts and buttons there was due to fungal infection and that the fungi present were common saprophytic forms.

Their investigations are not yet finalized, and there is still some controversy as to whether unfavorable soil conditions or particular insects are the more potent cause of nut-fall, although accumulated evidence shows that insects may cause the bulk of the drop. It has been shown by the entomologists mentioned that the noted distribution of the plant bug *Amblypelta cocophaga China Family Coreidae* closely corresponds with the occurrence of the nut-fall areas.

It appears certain from the following experiments that a decided proportion of nut-fall in the British Solomon Islands has been caused by *Amblypelta*. Lever,[41] at first working with Pagden, conducted caging experiments at Gaudalcanal Island and Gavutu, and in the first instance caged twenty palms and left 25 intervening palms uncaged and found that an average of 85 per cent. of the caged trees bore nuts against only 50 per cent. of the uncaged trees. Thus, although larger numbers of cages may have been more conclusive, the point seems to have been made that the cages prevented the access of some insect which causes the young nuts to fall.

All other insects were excluded and nymphs and adults of *Amblypelta* placed in the various cages. It was found that 90 per cent. of the nuts fell in the cages where the *Amblypelta* was enclosed and only 70 per cent. in the enclosed cages without the insect included. Thus it was shown that only 30 per cent. of the nuts would mature in the control cages even in the absence of any insect. This shows that *Amblypelta* by itself can cause two-thirds of the remaining nuts to fall.

Axiagastus cambelli was also suspected, but although results obtained by caging this insect were inconclusive it was apparently not important. In summarizing it is seen that by caging inflorescences with one-half of the palms having the insect in the cage and the other half serving as controls not having the bugs inside, there was a difference of 20 per cent. in the resulting nut-fall.

Phillips and Lever[42] repeated these experiments and recorded a mean difference of 26 per cent. between the nut-fall induced by the insect *Amblypelta* and the natural nut-fall. It was mentioned that this latter agreed very closely with the ratio estimated in the field, and given as two-thirds of the female flowers setting. It was also stated that *Amblypelta* was not found on the Russel Islands, where nut-fall was not so prevalent.

Prior to the discovery of the association of *Amblypelta* with nut-fall in the Solomons, these nut-fall areas were inspected by the present Director of Agriculture from this Territory. It was seen that the areas, where the nut-fall was most prevalent in the Solomons, were not, in his opinion, particularly fertile and, further, that lalang grass and low-lying swampy patches were present in several areas. The writer, when passing through these islands on his way to Australia, noticed that palms on some of the areas showed evidence of soil exhaustion, but

owing to lack of time was unable to find out whether this was confined to plantations suffering from nut-fall or not. It has since been ascertained that apparently healthy palms are liable to nut-fall where *Amblypelta* is present.

Nevertheless, it is feasible to believe that the effects of insect attack on the nut-fall could be worse under unfavorable soil, cultural and climatic conditions. In other words, where both the *Amblypelta* and bad soil and cultural conditions were in evidence, a greater percentage of nut-fall might occur. Further results of the work in progress will be looked forward to with great interest. Control of *Amblypelta* is being attempted by the introduction of egg parasites which attack the eggs of a closely related insect in the East Indies. Predators and parasites of the adult insect are also being studied as a means of control and for possibilities of introduction.

The Nut-fall Problem in New Guinea.

From a perusal of the foregoing literature it is seen that there has been a considerable diversity of opinion as to whether soil conditions, insect pests, fungus pests, climatic and pollination conditions, i.e., faulty nut setting, or a combination of several circumstances, are responsible for nut-fall. Thus, this problem has been investigated in various countries by entomologists, mycologists, botanists and soil chemists.

It appears that the term "nut-fall" is comparable with the term "bud-rot", and refers to a symptom or a condition rather than a definite disease. It may be sporadic or general in its incidence and due to a variety of causes. In only scattered instances has nut-fall presented any serious problem in New Guinea, and apparently it is not so prevalent as in the British Solomon Islands. Severe incidences of nut-fall have been recorded only at intervals on plantations in this Territory. Recorded instances have been received from plantations on the New Guinea mainland, New Britain, New Ireland, New Hanover, Tabar Island, Bougainville Island and Dampier Island. It has been undoubtedly present on other areas at various times, but the occurrences have not always been reported to and investigated by this department.

Bryce, writing in 1926 in answer to an inquiry from Bougainville Island on the subject of nut-fall, stated "that this condition had been the subject of investigation in Ceylon, where it has been caused by climatic conditions or a fungus which is found in most coco-nut countries, including the Philippines (obviously meant *Phytopthora*). There is, in addition, in New Guinea a small caterpillar which enters very young buds at the base and causes their fall".

It is impossible to say which of these three causes was present on the plantation in Bougainville Island, but most likely it was the caterpillar, although the climatic factor may also have been at work. It was suggested that the nuts be examined for the caterpillars mentioned, though, unfortunately, the life history of this pest is completely unknown. The only remedial measure suggested was the immediate collection and burning of the fallen nuts which were affected.

It would appear in several recorded instances of nut-fall in this Territory that insects probably had a decided influence on the occurrences, thus bringing the inquiry largely into the province of the entomologist.

Froggatt[31] associated an occurrence of nut-fall at Tabar Island with the stink bug, *Axiagastus cambelli, Dist.*, while the spathe borer, *Terathaba rufivena Walk*, was also bred out from the affected parts. Both he and an inspector and

instructor, who had previously seen the area, mentioned that the soil conditions were rather unsatisfactory on the plantations where this nut-fall occurred and that a proportion of both large and small immature nuts dropped. He described how the stink bugs obtained their food at all stages of development by puncturing the surface skin of the spathe or button by means of a sharp-pointed proboscis or trunk. The sap was sucked out so that the spathes and buttons tended to dry out and drop the nuts. It has since been ascertained that, where this rather serious nut-fall occurred at Tabar, after a period of six to nine months, the plantation recovered. Although spathe borer was present, the soils on the plantation in question were hard, red and clayey and the nut-fall occurred during a dry spell after heavy rains.

A reported occurrence of nut-fall on Tabar Island was investigated recently. Comparatively few new nuts were falling when the plantation was visited, although there was some evidence of nut-fall some time before. The soils here were not very suited for coco-nuts and the production had commenced to decrease noticeably.

A description of the soils here should indicate the reasons why nut-fall has been seen from time to time in the Tabar Group, excepting that very little is seen where the coco-nuts are growing on well-drained, coral foreshores.

The ground rock appeared to be a syenite porphry which weathers into a very stiff, clayey soil while the subsoil is clayey, greyish and also very heavy. This stiff soil is present on the hills as well as on the flatter foreshores, and the fact that water was held on the sides of such high hills showed its capacity for pugginess and retention of water. In many places the country rock reached to within a few metres of the surface. Some of the flat areas were also heavy and swampy and showed only a limited response to draining. On such flats where nut-falls had been apparent before, the bases of the palms were very exposed and the ground compacted.

Cattle grazing over such areas left deep foot marks, and only added to the trouble; even more so on the hills than on the flats, as the foreshore palms, on a narrow, coral and sandy belt, appeared quite healthy and produced heavily. Such heavy soils must suffer from the effects of any dry period, because after being very wet and stiff, they would dry up and crack during dry periods. The presence of seedy grass, *Chrysopogon aciculatus,* on such areas was also very detrimental to the palms.

In material collected from areas where some nut-fall occurred on Kar Kar Island, New Britain, New Ireland and New Hanover, specimens of *Tirathaba rufivena,* spathe moths, were bred out and recorded by the entomologist.

Sexava spp. and *Promecotheca,* when present in epidemic form as is the case on some plantations at the present time, do cause considerable amounts of immature nut-fall.

The following notes were taken recently on nut-fall caused by *Promecotheca* on one plantation in New Britain, where the insects are present in epidemic proportions.

Here nut-fall of three types was apparent.

Firstly, small green nuts were to be seen everywhere, which were smaller than an orange in size and fell singly from the trees.

Secondly, medium sized to large nuts were seen to fall singly, the bigger nuts bursting as they hit the ground.

Thirdly, whole spathes of green nuts (Kaulaus) were seen to fall together, which, although full of liquid, were quite immature, showing little or no kernel, and in any case the meat rotted when left on the ground.

Where almost mature a big proportion of the nuts became rotten and the button became so soft and soggy that one could push a finger through it.

Promecotheca and *Sexava* cause the fronds to die and fall prematurely, and also greatly reduce the leaf feeding area so that there are insufficient nutrients absorbed to ripen the nuts.

In portions of one plantation in New Hanover (Lavongai) the stink bug, *Axiagastus cambelli,* has reached such epidemic proportions as to cause young nuts to fall in large quantities where they have not already destroyed the flowers. The insects are present in unbelievable numbers causing the spathes to appear black. At present, it is only on this area that the insect is known to be serious in this Territory.

The species *Amblypelta cocophaga,* associated with nut-fall in the Solomons,[21-41] has not yet been recorded here, though the possibility is not overlooked that it may have spread to Bougainville Island which is really of the Solomon Islands group. Nut-fall, however, has not been of particularly frequent occurrence, nor very serious in its effects over wide areas of Bougainville Island. It is most likely that nut-fall is not so prevalent in New Guinea as in the Solomons, because the species of *Amblypelta* found there is not present in this Territory, but this remains to be proved.

According to China[21] there are four unidentified species of insects, derived from New Guinea, closely related to *Amblypelta,* stored in the British Museum, but the Territory and locality where they had been collected was not stated.

Phillips stated personally that a species of *Amblypelta,* namely, *A. fumosa,* had been recorded from Kinigunan, New Britain, by Dr. Blote, but this was not the species responsible for the trouble in the British Solomons. Search showed that this species must be scarce here. Study of the distribution of *Amblypelta spp.,* here is a matter which is receiving the attention of the entomologist.

Although it has been established that insects cause a proportion of nut-fall in various areas, it must be remembered that a number of other causes have been proved to influence serious nut-fall in other countries. The presence of fungi, unfavorable soil conditions, various deficiency diseases, faulty pollination, &c., must not be overlooked in any specific investigation of nut-fall.

It was seen by the experiments in the Solomons that approximately a 60 per cent. natural fall was recorded. Some natural fall occurs everywhere but what is considered a good setting of nuts to flowers pollinated has not yet been established.

The author has had a great deal of association with pollination problems in temperate crops where it was regarded as a fundamental fact that in some fruits the number of fruits carried to maturity may be dependent on several limiting factors. The amount of fruit which matured and the windfall problem were closely associated with the environment, thus the vigour of the trees, state of the soil, and water conduction and requirements all had their effects. It was proved that, all things being equal, the most vigorous trees of any particular variety could carry the most fruits to maturity. Thus, coco-nut palms growing under unfavorable soil conditions, e.g., in heavy soils with bad drainage, may behave similarly and drop many more young fruits than healthy palms growing under favorable circumstances.

Another observed fact in this Territory is that the occurrence of nut-fall is more frequent in old plantations. It has been noted in several instances that, where cattle have been grazed and tramped over heavy soil where coco-nuts are growing, much more nut-fall has been induced.

In young palms immature nuts have been observed to fall frequently, in New Guinea, even after they have reached a good size. It appears that some young palms have not sufficient vigour to bear (to maturity) all of the nuts which set; this appears to be particularly the case where the soils are heavy.

An occurrence of nut-fall appeared on one large plantation in Bougainville where about 200 acres were affected, but this area has recovered and is now yielding well. The only area in which nut-fall occurs at present is in a wet, trodden area near a cattle dip, as several hundred cattle are kept on this plantation. The base of the coco-nuts showed that a small borer was present (the identity was not determined) but the question is why had this not spread over the plantation if any insects were the primary cause of the condition? It was seen on these palms that there were plenty of healthy fronds, but no nuts remained on the palms. The soil horizons where the wide area of nut-fall had occurred previously were examined and proved very interesting. This plantation is situated close to a semi-active volcano which has given off explosively a very tuffaceous, light soil with some belts containing pumaceous rock. The soil is lighter in colour, texture and composition than most soils in Bougainville. It appeared that there had been a fluctuating deposition of soil probably in many instances re-deposited from shallow streams. It also appeared that the sea had covered the area at intervals and that a silting and re-deposition of fine particles had occurred. Thus some of the previously affected area was very low-lying, with water still present, rendering drainage essential which, when carried out, greatly improved the appearance of the affected areas. On an exposed section in a natural gully, it was seen that there were alternating layers of fine and coarse soil and in some layers sandstone rocks occurred which were very crumbly and easily broken; this was particularly evident where a quarry had been made.

The explanation of the recovery of such a large area from nut-fall might be that the rest of the palms had, at one period, struck a gravelly layer and then, after a lapse of time, penetrated to the better soil beneath. Palm roots were seen at from 18 feet to 20 feet in the gully mentioned. Again, the draining of the stagnant water must have been very helpful to their recovery.

The manager stated that heaping up the fallen fronds around the palms, adding as much humus to the soil as possible and draining to better the soil conditions aided the palms to recover, and that manuring should have been beneficial.

The occurrence of single palms in a plantation showing all the evidences of nut-fall has been noted here which may be a hereditary effect or due to local compacting of the soil, e.g., near a copra drier.

It is difficult to believe that an insect infestation would have confined itself to an area which was less than one-tenth the total area of the plantation and afterwards cleared up almost completely. In any case if insects did cause a percentage of the nut-fall it was evident that the soil conditions were at fault in the area where nut-fall occurred.

A recent development of nut-fall here is an isolated case on the mainland of New Guinea, where an old plantation is showing rather severe evidence of nut-fall. The conditions responsible have not been fully investigated but some conclusions are possible at this stage.

Reference to the photograph on page 58 will show that nuts at all stages of development have fallen in this instance. This photograph depicts the specimens derived from one kerosene case of fallen nuts which were sent in from the plantation. These specimens were also microscopically examined within a couple of days of their being picked up at the plantation and while they still appeared fresh and green or slightly yellow, according to the age of the nuts when they fell. Reference has been made to recent reports concerning the plantation in question. It appears that the greater proportion of this area was planted around the years 1898-1904, hence most of the palms are now approximately 32-38 years old, although some were planted in 1914-16. According to an inspector and instructor (Mr. Corfield) in 1933, the palms had "gone off" and were bearing poorly, as there was not much depth of soil above the coral and the humus and manurial constituents had been greatly depleted. He also recorded that 150 palms had been affected by lightning within six months and had to be destroyed. It has been stated that the plantation was continuously grazed with cattle since 1918 at least, and that often 300 head were present, which led to soil compacting under the particular conditions, and further that bracken and weed growth were plentiful.

Some interesting technical data was obtained from the examination of the specimens of the fallen nuts submitted. The greater proportion, about 60 per cent., of the nuts which fell were small, ranging from $1\frac{1}{2}$ inches to $2\frac{1}{2}$ inches in diameter. The fall of the small nuts may be a natural response to any unfavorable environmental conditions, either soil, climatic or cultural. Numerous nuts, however, which were on the ground were quite large, ranging from $7\frac{1}{2}$ inches to 8 inches in diameter, and it is likely that other causes might have been responsible for their fall.

In several cases the presence of large boring insect larvae was noticed and these expelled great quantities of brownish lumpy fruss from a hole several millimetres in diameter. Some of these nuts were placed in specimen jars, where it was seen that these larvae kept on boring for several days and are still in the larval stage. It appears that the larvae is *Lepidopterous* and is probably the spathe borer—this will be confirmed when adults are bred out.

Indications of the presence of such a boring caterpillar were absent in several of the coco-nuts examined and there was little evidence that they had attacked the spathe higher up.

On practically all of the nuts examined, evidence of fungus attack was seen. This was not always the case where freshly fallen nuts were examined in the field. A number of the nuts showed splitting and gumming, probably due to the fall; others showed a dark brown discolouration at the stalk end which, when the nut was split open, was shown to extend well into the internal tissues. Practically no kernel or meat was present in any case examined. The thin kernel, where present, was usually brownish and discoloured similar to a potato affected by Virus or Irish Blight. Under the bracts forming the cap or button, which remained attached to the nut, a red discolouration was apparent in several cases on what appeared to be healthy tissue, although it had a tubercular, lumpy appearance. Culturing and examination of this tissue showed that a definite fungus was

responsible for the discolouration. In other cases it was seen that a brownish discolouration extended more than half-way along the length of the nuts and that pycnidia (perfect fruiting stage) of some fungus were present.

A diseased nut was cut open and kept under moist conditions and a profuse fungus mycelial growth developed which was at first whitish and later smoky in colour. A distinct reddish-brown gummy ooze was exuded, as was seen on some other specimens. The fungus present here was apparently *Thielaviopsis paradoxa*, which is widely spread in New Guinea and was recorded as causing nut-fall in Porto Rico in 1925[23]. The perfect stage of the fungus seen is of technical interest as it appeared like a Trichosphæria or Sphæronema (*Ceratostomella*), and is being sent with the other specimens to the Imperial Mycological Institute for definite identification. It appeared from what could be seen on the field that fungi were probably not the primary cause of nut-fall in this case.

As could be expected, there were several fungi present which appeared to be secondary in their effect, such as *Fusarium spp.*, and *Pencillium* (green mould). It is also feasible that insects would attack nuts on the ground.

It is probable that the fungus proved more serious where old palms under poor conditions showed reduced vitality, especially as *Thielaviopsis* and spathe borer are known to be present on many plantations here. *Thielaviopsis* is often seen on lightning-struck trees or on badly-drained areas.

Investigation showed that grazing cattle over wet areas both on this plantation and on a neighbouring property adversely affected the soil in many instances, but this was worse in some places than in others, especially where water was seen to collect on old camping grounds. It was also noted that the nut-fall was worse on some areas of the plantation than in others, and further that some palms shed many more nuts than others. This compared with what has been noted by investigators in Ceylon.

The soil on the plantation in question is a sandy coral loam on the foreshores with practically pure coral at only a small depth ranging from a little over 1 foot to less than 2½ feet from the surface. At the back of the plantation the soils are heavier, containing more volcanic soil mixed with the coral outcrop, while the subsoil is clayey. In some areas the shallow soil overlies compacted rock coral which appears to act as a hardpan, a condition which has been seen elsewhere in this Territory. The soil at the back of the plantation appeared to cake and crack under some conditions, while in most areas (on the plantation) the rain disappears quickly after falling, creating liability to the effects of drought. On many areas the water rises close to the surface and a considerable proportion of the total area is comprised of swamps and lagoons whose distribution would, no doubt, be greater in the wet season.

The effects of the shallow soil and the presence of hard coral caused the basal roots of the palm to be raised high above the soil level during the process of growth, as they could not penetrate readily. Examination of the soil horizons in many holes which had been sunk for road-making showed that the rooting of the palms on this place was shallower than had been seen on other areas. The effect of such shallow soil on raising the palms out of the soil had been, in many instances, increased by the tramping of the cattle.

A great proportion of the palms are situated on a narrow isthmus, which appeared to be liable to heavy winds. The plantation is particularly liable to lightning strike and several hundreds of palms have been cut out from this cause.

In one area the unusually large number of 45 palms were cut out as being affected. The susceptibility of particular areas to lightning strike is often influenced by local conditions and the reasons for this are discussed elsewhere.

"Leaf droop" was observed very commonly on the plantation. This condition had already been recorded by Petch[84] in Ceylon as being associated with nut-fall, where he described the leaf droop to a species of *Phytopthora,* as was the nut-fall; but this was not the case in this instance.

The fronds which hung down were bunched and dead, or nearly so, while the upper fronds often appeared quite healthy. In Ceylon the leaves were said to bend frequently while still green. In this instance *Marasmius* thread blight, not to be confused with true thread blight, was seen quite commonly at the base of the fronds, and appeared to have progressed much more than on normal fronds. The bases were noticeably very rotten and often became infested with white ants. The leaf scars appeared close together while the dead spathes usually remained attached to the palms. A case of an otherwise healthy leaf attacked by white ants was seen here.

Leaf droop in New Guinea appears to be associated with poor soil conditions and with poor vigour of the palm. It was seen, however, in some cases, that palms which were not affected with leaf droop dropped their nuts.

Many spathes and fronds from palms showing a good deal of nut-fall were cut down. A good proportion of the spathes showing such nut-fall were found to be affected with the spathe borer *Tirathaba rufivena.* In some cases where large nuts had fallen this could be put down to spathe borer and one case where this unquestionably occurred was noted. Several spathes from which nuts had fallen showed no disease effects at their base and were not affected with spathe borer, hence nut-fall in these instances must be due to other causes, such as faulty pollination or unfavorable environmental conditions.

Where nuts of all sizes have fallen there is probably more than one cause indicated. It was certain from the presence of withered, immature nuts on the ground that nut-fall had been in evidence here for some time. Nut-fall was found to be present on other plantations on the mainland in close vicinity to the one in question, but was apparently not so evident. Probably there are few plantations where there are not some immature nuts on the ground as, for example, nut-fall has been recorded on the relatively rich soils of Kar Kar Island.

Weed growth was rather plentiful on the plantation under investigation, although there was not nearly so much Kunai (*Imperata arundinacea*), except in the back areas, as in several other parts of New Guinea—Ferns, seedy grass, *Chrysopogon aciculatus, Stachytarphetum* (Blue-flowered weed), *Elatostemma* (with spiked seeds), *Sida retusa* (= *S. rhombifolia*), *Mimosa pudica* and *Ipomoea spp.,* were among the weeds present. Epiphytic ferns and staghorns were very plentiful on the palms and, although these latter may have no ill effects, they indicate the environment.

A study of the incidence of rainfall on the particular area shows that, for all of the eighteen years recorded, July, August and September are usually dry months, following the wet season, while the rainfall for October is inclined to show more variations in different years. The average rainfall is about 140.54 inches per annum, and, although the rainfall for 1936 closely approximates the average for the period, some wide deviations occurred, the fall being much lighter in April and June than is usual and much heavier in August. Since 1926 the

average rainfall has fluctuated from 101 inches in 1934 to the fairly high total of 153.28 inches in 1935, while 249.36 inches were recorded in 1930 as against the next lowest total rainfall of 113.57 inches in 1931. Such pronounced fluctuations in rainfall could be expected to influence the yields greatly and also the number of nuts carried to maturity in particular years, especially on soils which are influenced by drought conditions, as are those on the plantation under consideration. It was stated that nut-fall was worse in certain seasons and also in some years under the circumstances obtaining there.

It is apparent that there are at least four conditions present in the case investigated which are likely to cause nut-fall, namely, soil and cultural conditions, age of the palm leading to soil exhaustion, fungus and insect attack, and climatic conditions. The natural soil conditions obviously cannot be remedied and similarly the natural climatic conditions, although fluctuating, will always exist. It is a well-known fact that coco-nut palms on a number of older-planted areas in this Territory have commenced to deteriorate owing to continued soil exhaustion. On such areas palms could not be expected to bear a large number of nuts to maturity regardless of the original setting after the first pollination. The most vigorous palms should carry the most nuts to maturity. Thus, coco-nut palms growing under unfavorable soil conditions, for example, on heavy soils with bad drainage or on soils liable to swamping under wet conditions, and drying and cracking under dry conditions, may be expected to drop more young fruits than healthy palms growing under favorable circumstances.

In addition to the remedies suggested by Stockdale[76] where the soil conditions greatly affected the nut-fall, mulching, cover cropping and selective weeding are also remedies which suggest themselves.

It appears unwise to allow cattle to wander *ad lib.*, over any plantation, and, if they are kept, proper subdivision of the area should be provided. This is especially true where the soils are heavy.

The question of the economics of keeping the cattle there, as against any damage to the soil conditions, must to some extent be assessed by the owners.

It is certain that the natural soil and climatic conditions which probably most largely influence the nut-fall cannot be remedied, and all that can be done is to provide good cultural conditions. The question of rehabilitation of old plantations is a vexed one which will be discussed elsewhere.

Dr. Phillips[85], during his recent visit to Rabaul, in October, 1936, kindly examined the nuts derived from the occurrence of nut-fall on the mainland. He was definitely of the opinion that this nut-fall was not due to the same causes as the Solomon Islands nut-fall. No evidence of puncturing by the *Amblypelta* bug could be seen. Thus, there is some possibility that this specific insect is not present on the mainland of New Guinea, although closely related types are present. He also stated that a most noticeable feature in most of the nut-fall areas in the Solomon Islands was that the palms and foliage were generally healthy, suggesting that the cause of nut-fall was not physiological. The coco-nuts which fell were generally smaller and did not reach the same size as a large proportion of those which he was shown from the specimens collected on the mainland.

Winds.

Heavy winds are a cause of nut-fall, and after some recent very strong winds in Namatanai, New Ireland, the writer observed that some large immature nuts had fallen. The nuts which dropped after such heavy winds showed practically no evidence of any injury or insect damage at the base. Crows have been known to cause nut-fall on Witu Island, while parrots and other birds do cause nuts to fall when feeding on the young spathes.

Rats as a Cause of Nut-fall.

Undoubtedly rats cause a considerable proportion of the fall of immature nuts which is present to a limited extent on most plantations in New Guinea. On some areas here, rats are plentiful, and, in many instances, have been known to climb the palms and chew the bases of the young nuts, causing them to fall. Rats usually continue eating the young nut on the ground, hence quite large holes may be seen at the bases of young nuts damaged by rats. Rats do damage to nuts which have fallen from other causes.

Rats have been recorded by Paine[49] as causing severe damage to young nuts over wide areas in Fiji. Taylor estimated that they caused 7 per cent. of the immature nut-fall over the entire Fiji group, while Paine, counting by another method, showed that from 31-46 per cent. of the young crop was damaged by rats on certain estates. The damage to young fruits was described as follows:—

"Most of the damage done by rats to the coco-nut crop takes place at the various stages of fruit development between pollination of the female flowers, and the final maturing of the fruit. Shortly after the fruit is set a cavity begins to form inside it in which nutrient fluid accumulates. Rats bite through young nuts at the base in order to obtain this fluid and in doing so dislodge them from the tree.

"Any nut which, as a result of rat injury, falls to the ground before the husk has begun to turn brown, is rendered unfit for harvesting, and these nuts, which are completely bored by rats, are common objects in coco-nut estates where rats are established.

"The rather ragged-edged holes, either at the side, or more usually near the base of such nuts, are so characteristic that in counting nuts lying on the ground there is no possibility of mistaking those whose premature fall has been brought about by rats."

Approved methods of rat control were outlined by Froggatt[30] in a recent issue of the *New Guinea Agricultural Gazette.*

RING DISEASE OF IMMATURE NUTS.

(*Recorded by Simmonds.*[66])

Stated by Dr. R. J. Noble, Biologist, New South Wales, to be associated with *Botryodiplodia theobromae,* but whether as a causative organism was uncertain.

Simmonds stated that the disease, which is characterized by a somewhat regular ring of lesions around the husk of immature nuts of various ages, which split at the affected points, was present to a varying extent everywhere in New

Guinea. When attacked early the nuts fail to develop and drop, but, if attacked later, develop and ripen as undersized and misshapen nuts; thus a considerable loss of half-grown nuts is caused.

It is only necessary to reiterate that up to the present time the great majority of the planters in New Guinea have had little to fear from losses due to nut-fall.

It is only in sporadic instances that nut-fall has presented any problems in New Guinea while severe incidences of nut-fall have been recorded only at intervals on plantations in this Territory.

It appears fairly certain that nut-fall caused by *Amblypelta* is not yet present here, and that soil and local conditions have been largely responsible for what nut-fall has occurred. It was thought advisable to present all phases of the problem, so that the local planters would be aware of the true position here.

HEAD DROOP (CORKSCREW, CABBAGE DROOP, STRANGLE DISEASE).

This is the most baffling coco-nut disease found in New Guinea. The condition is widespread but is particularly serious in parts of New Ireland. In Bougainville, "head droop" is seen in a relatively few scattered palms only. It is also present in New Britain and on the mainland of New Guinea. According to a resident German planter, this disease was investigated during the German régime here, but neither bacteria nor fungi were found as casual agents. Recent examinations have also produced negative results.

In the condition of "head droop" it is seen that the top bends over, and in many cases the whole stem may form a complete semi-circle, while the leaves are all bunched and twisted into a distinct rosette, with the lower leaves sparse, short and dying back. In many cases the whole stem may form a distinct loop, or in some cases become "S" shaped. In the final stages there is failure to bear coco-nuts, while the spathes may die back completely. These abnormalities cannot possibly be hereditary or genetical, because many palms recover and the condition may recur several times on the one palm. As far as is known virus diseases have not been recorded in coco-nuts, and the author has only read of one case where such a condition was suspected. Park[52] has described a suspected virus disease on Areca palms (*Areca catechu*) in Ceylon, but the symptoms are quite different from those described here. There are numerous examples of virus diseases in the plant and animal worlds, e.g., bunchy top of banana, mosaic of tobacco, bronze wilt of tomato, and an ordinary cold in man are usually suspected of being due to virus infection. The causal agents of this type of disease, although usually infectious, are not visible even under the highest magnification, but, in the case of plant diseases, they are usually transferred from plant to plant by an insect carrier (vector); e.g., thrips, at a particular state of development, are responsible for the spread of bronze wilt of tomatoes, and the banana aphis spreads the banana bunchy top virus.

It has been stated that insect injury to the growing point, in the early stages, may weaken one side of the trunk and eventually lead to twisting. The association of this condition with mealy bugs, scales and aphids was recorded by

Simmonds in 1924, but he stated that they were apparently only secondary effects. It has been suggested by some planters that this condition is due to original twisting of the stem and roots when the seed nut is germinating. If such were the case, it is difficult to believe that it would be more prevalent in some districts than in others. Then the fact that the palms often recover seems to discount this theory.

The present author noticed that on most of the affected palms, red tree ants (*Oecophylla Smaragdina Latc.*) were more plentiful than on other palms, but whether this was because of the extra protection afforded by the bunched leaves, or

HEAD DROOP (Typical).

HEAD DROOP.—Apparently recovered Palm leaving a very twisted stem.

because more scale and aphids were present, it is not possible to state. It could be assumed, however, if "head droop" were a virus disease, that sufficient insect vectors or carriers were present to aid in its dissemination. It is suspected, from analogy and comparison with the symptoms found in other virus diseases, that "head droop" belongs to this category, and further work is necessary to prove whether this contention is tenable. The fact that in many plantations the affected palms only occur at scattered intervals shows that in some places the disease does not tend to spread rapidly.

There is the possibility that "head droop" is a deficiency disease, but this seems improbable, as the condition is widely spread in New Guinea, and is quite prevalent in rich soils, such as in Kar Kar Island. Often the best-bearing palms are affected, and the foliage does not appear in any way chlorotic, being usually deep green in colour. There is also the somewhat limited chance that where palms are growing on rocky areas the resultant restriction of roots would lead to unbalanced growth. It is also possible that where odd palms are affected, e.g., in New Britain, the cause of "head droop" is not the same as where the condition is prevalent and tends to spread, as in New Ireland.

"Head droop" was apparently referred to in Simmonds' short description of "strangle disease",[66–67] where it was stated that a number of trees with the heads bent and twisted and having a strangled appearance were seen. Various suggestions as to the cause were put forward. The most probable, however, seemed that the trees had been injured by one of the big beetles.

The Manager, Bopipe Plantation, Namatanai District, New Ireland, recognized an apparently unclassified disease in February, 1924. Bryce, in a letter referring to this occurrence, stated that probably three diseases were indicated in the field symptoms described, namely bud-rot, deformity of growth, and withering of leaflets (probably due to soil exhaustion or insect attack). This "deformity of growth," also referred to as turning over of the terminal bud, was, undoubtedly, what is now called "head droop." It was suggested that an efficacious remedy was to cut off and tar the central shoots. The Manager, Bopire plantation, cut about 25 palms in this manner, and six weeks afterwards he maintained that they all started to grow on healthy and straight. The original record by the Manager is worth quoting as good practical observations, although some of his conclusions were untenable:—

"The infected palms were planted in 1919, and, except for a few detached palms near the seashore, were mainly confined to an area of about half an acre in extent. The first symptoms were the turning over of the terminal bud plus a dying and withering of the leaflets on the central fronds. Later, unless remedied, the bud will become rotten and stinking, and on cutting be found to be infested with the small palm weevil. No sign of root disease was found. From observation of the infected palms and their response to treatment, the idea was gained that the original damage was caused by whirlwinds, which were very severe and frequent where the diseased patch occurred, and whose force wrenched and screwed the centre shoot of the palms, and in doing so loosened the cohesiveness of the leaves comprising the central shoot. In this weak state they are a prey to all diseases, while leaf-eating hispids and palm weevil find an easy entrance. It was stated that all the buds lean over in the opposite direction to the north-west winds, due to effect of these winds on the previously weakened buds. This was not the first time that palms showing the centre shoot leaning over had been seen and treated, but it was the first time that a collective area was attacked and looked so bad as this one did."

Froggatt (1934),[31] in an unpublished departmental report, stated that the "cabbage droop" reported from Namatanai should, he considered, be more properly considered as "head droop," because the whole head of the palm inclines over at an angle of up to 90 degrees, or even more, in some instances. It may also be much less. The time occupied in the "droop" is variable, and may take

up to twelve months or more, before the head begins to right itself. During the period of "droop" no spathes are developed, although the leaves remain green. After righting itself spathes are again developed in a normal fashion.

Cases were reported in which the palm had died before the head again turned into the vertical, but this is apparently rare. It is of general occurrence throughout the area traversed. It may be stated that it has been observed in most other parts of the Territory visited, but in the New Ireland area it may be more prevalent than elsewhere. The occurrence of "droop" is not, apparently, entirely a question of location, as it occurs on both the sandy loam fore-shores and on the back areas, where the soil is of clayey nature and rather stiff when wet. It was reported, on some plantations, to be more numerous on the back areas than on the frontage. An examination was made of the root system, and on the clayey areas surface roots seemed relatively scarce, but were more numerous on the fore-shores. The nature of the soil may, of course, have masked the true conditions of the former. On some plantations, he was informed that the "droop" had been of more common occurrence since the very dry climatological conditions experienced in 1933 and early 1934. The soil types present on most places were sandy loams on the fore-shores, with clay loam overlying stiff, reddish clay right to the surface. No pest or disease symptoms which might have been causative factors were observed.

Attempted systems of control practised on different plantations were as follows, but, as no control or check palms were kept in any case noted, it was not possible to draw any conclusions regarding their efficacy:—

1. Three partial scarfs, one above the other, encircling the whole palm.
2. Cutting the fronds on the side of the "droop" and the top of the "head" above the cabbage.
3. Leaving all the fronds and cutting the head above the cabbage.
4. One scarf cut on the side opposite to the "droop."

The objectives and likely influence of such treatments, under the circumstances, are not clear. A considerable number of affected palms, to which nothing had been done, were observed to have righted themselves (e.g., on Panaras Plantation). He concluded that further data were required before any opinion could be formed as to the disease in question.

In 1934 the following record was received from Samo Plantation, Namatanai, New Ireland, where there were a number of palms suffering from "cabbage droop." In some cases the young palms had not made any butt, yet the terminal shoot was curled right over. Various methods of cutting back were tried, but the majority of palms curled again. Palms in bearing, suffering from droop, were also partially ring-barked, with similar results. One planter from the mainland stated that, by continually cutting back the fronds, as the head periodically drooped, he was able to save many palms.

The following is a description, by the present author, of a palm affected with "head droop" and cut down for examination on Koka Plantation, New Ireland:—

The trunk was badly twisted in two directions; the second twist occurred about 2 feet above the first twist, which made the palm almost "S" shaped;

thus in the last twist the base of the fronds was facing in the opposite direction to the first twist. The fronds comprising the head of the palm were all bunched together, and it appeared that the central leaves were the first to bend over, and eventually the extra weight on one side caused the whole head to fall over. It appeared that the sheaths or bases of the leaf "petioles" (leaf stalks) were bunched also, tending to become very tight, and that the leaf bases were closer together than usual; thus the whole of the fronds formed into a closely compacted clump and fell over at the top. The stalks, or petioles, of the leaves developed a distinct curl or twist, and cracking was often seen where the twist occurred. The fronds curled in a complete arc, while the pinnules of the leaves (leaf divisions) folded noticeably over the central vein. The affected leaves were not a healthy green colour, but appeared to have a silvery-coloured sheen caused by "silver-leaf disease." One of the outstanding symptoms was the failure to bear nuts at all; also the flower clusters were affected, and the smaller branches of the spathes died back.

Another palm, cut down on Patlangat Plantation, showed the trunk bent over into a complete semicircle, while altogether the trunk showed four distinct twists, the first appearing quite close to the base, showing that the palm was affected for a very long time. The fronds were all bunched and twisted into a distinct rosette, while the lower fronds were sparse, short and commencing to die back. It was also noticed that the pinnules (leaf divisions) were sometimes broken on the bending side. On one palm the growth was checked about two-thirds of the way from the base to the top, and it was seen that there was a marked constriction of the leaf scars where the twist occurred.

On these plantations they had tried cutting the tops, i.e., the overhanging fronds and terminal shoots, but with mixed results, and, although some of the palms recovered and grew straight again, this was also noticed on palms which had not been touched. The disease does not appear to kill the palms, as they keep growing for years, and may apparently recover and bend again; sometimes four or five times. When the cabbaging phase does occur, however, nuts are rarely set. One palm which was previously a heavy bearer did not bear for three years, owing to "head droop," then recovered and commenced bearing very well again. Undoubtedly, "head droop" appeared to be the worst disease present on the west coast of New Ireland. It is not so frequently seen in young palms, although it does occur in two to four-year-old palms. It was stated by the owner at Patlangat that he noticed general debility and weakening of the palms before they commenced to droop over.

On one plantation 144 palms were cut back within twelve days. One palm, which was about ten years old before twisting occurred, was cut back several times; it recovered for a while, but finally developed the droop again. Another palm treated in this manner was finally killed out with red palm weevil. On the east coast of New Ireland "head droop" is present on several plantations, but does not appear as prevalent as on the west coast. On some plantations they were trying to remedy the position by removing the overhanging fronds and loosening the leaf sheaths, and, although in a number of cases the palms recovered and became apparently normal, the greater number tended to screw again. It

is suggested that it would be definitely unwise to select seed coco-nuts from areas where "head-droop" is prevalent, and that even good palms close to a palm suffering from "head droop" should be avoided.

If aphis are responsible for carrying a virus disease, as is suspected, a method of treatment which suggests itself is spraying the palms, after cutting back, with a tobacco infusion or with black leaf 40 (= nicotine sulphate), using a strength of 1 in 500 to 1 in 800. Experiments are necessary to see whether these or other sprays, such as tar distillates, red or white miscible oils, &c., would prove in any way efficacious. If the disease is observed in young coco-nuts, or where it is just starting, it would be a wise course to cut out and destroy affected palms.

In conclusion, it may be stated that, while some of the remedial measures referred to may be of value, it is impossible to recommend any form of treatment until the cause of the disease is definitely established.

FROND CHOKE.

In this case the terminal fronds tend to stand very erect and develop poorly. The outside leaves appear to be closely crowded around the growing point, and their bases are held together, instead of growing free. The following fronds gradually become smaller and smaller as fresh ones appear, while the palm develops a sickly, yellow appearance, and appears to lack vigour. As far as can be determined, there are no fungus pests responsible for this disease. It has been suggested that it is aggravated by close planting, bad soil conditions, &c. Again there is the possibility that this is a virus disease, but as the condition is confined to definite patches in some instances this suggests some physiological derangement.

Ashby[4–6] described "little leaf disease" present in the West Indies, where the central shoot sends out a succession of crumpled and distorted leaves, which become progressively smaller until they are completely dwarfed; the upper surfaces of the leaf-stalks show raised brown stripes and patches, which become woody and cracked. The rigidity imparted to the central shoot by these indurated leaf stalks is apparently the cause of crumpling, and, in part, distortion of the young leaves. Spontaneous recovery not infrequently occurs, or occasionally the bud may wither or soft rot. Recovery was much facilitated by slitting the strainers of the central leaves and pouring into the heart a diluted tobacco extract. He also stated that the cause of this peculiar condition is obscure, but quotes the work of Earle in 1912,[26] who studied "*little leaf*" in Cuba, and concluded that it was caused by an attack of aphis on the very young leaves in the shoot. The aphis was tended by ants, which probably were responsible for transporting it, hence the efficacy of the contact insecticide is explained. The condition described by Ashby[4–6] closely resembles the "frond choke" present in New Guinea, which is often accompanied by a similar crinkling of leaves. The author is of the opinion that, in some palms, "frond choke" and crinkled leaf may be of genetical origin, as some of the palms have been seen to remain permanently affected and not respond to treatment.

It appears that certain types of palms which are very erect growers are more liable to "frond choke" than others. Where this condition is present it is wise to improve the cultural conditions, and also loosen the overhanging fibrous tissues at the bases of the constricted fronds.

COCO-NUT THREAD BLIGHT.

CORTICIUM PENCILLATUM, PETCH.

A new Leaf Disease from New Guinea.[16]

Described by G. Bryce, D.Sc., Edin. (1924).

A leaf disease of coco-nuts has been intermittently reported from plantations in New Ireland since 1921, and no doubt it has been known locally for some considerable time. The disease is a thread blight and the causative fungus has been described by Petch as *Corticium pencillatum n.sp.*, neither the disease nor the fungus having been previously recorded. Other palms growing in the forest are said to be attacked, and these therefore constitute a source of infection for coco-nut plantations.

Identification.—The fungus mycelium (thread) runs along the under surface of the rachis (midrib) in slightly elevated strands, up to 1 mm. broad, which divide at intervals of about 3 cm. into a fan of pencillate branches, thinner than the original, with the exception of one which continues as the main cord. The latter runs in long curves from side to side of the rachis, the intervening spaces being partly covered by the fans of finer strands. Where the mycelium has spread from a leaflet to rachis, several stout cords may radiate over the rachis from the base of the leaflet. On the leaflet, the mycelium spreads lengthwise in similar but flatter strands. There may be two or three main strands on a single leaflet, all branching in the same manner. Ultimately all the strands are united by a thin film of hyphae which may extend completely across the leaflets. This film develops basidia everywhere, so that the leaflet finally bears extensive, thin, continuous, powdery, white patches.

The superficial mycelium is confined to the under surface of the rachis (leaf stalk) and, in general, to the lower side of the leaves. But, where the diseased leaf tissue has cracked, it may extend through the crack and run along the upper surface in a fine strand by the side of the midrib, on that side of the leaf which is nearest the rachis when the leaf is folded. The fungus attacks the leaflet and kills large areas, its effect being conspicuous by the production of a large white patch on the upper surface, which contrasts strongly with the normal green of the surrounding tissue. The colour of this patch is not due to fungus tissue; there is no external fungus on it. It is caused by the separation of the upper epidermis from the dead internal tissue, with the consequent formation of a large blister.

Occurrence.—The fungus is known, so far, only on the coco-nut palm and it has been observed only in New Ireland and New Hanover. The older leaves of the palm are attacked and sometimes as much as one-third of the crown is involved. Diseased leaves are shed earlier, and the distal portion of a diseased leaf, though still green, cannot be of much service to the palm owing to the presence of an area of dead leaf tissue between it and the leaf base. Frequently quite extensive areas of plantations are badly diseased; in one case an area of about 160 acres was heavily attacked. Though the disease does not yet apparently kill the palm, it has a serious effect in reducing the leaf surface and in thus lowering the rate of carbon assimilation. Such an effect is, of course, immediately and necessarily followed by a reduction in crop, which is frequently long continued.

Treatment.—The first step to be taken on a diseased area is to cut out and burn diseased leaves. The remainder of the crown may be sprayed with Bordeaux mixture. Field observations, however, tend to show that where large areas are affected the disease has been allowed to run on unchecked for several years. The disease is at its worst in the wet weather of the north-west monsoon. Excision and burning of diseased leaves would therefore be most easily carried out in the season of the south-east trades.

Corticium pencillatum, Petch.—Mycelium hypophyllous, spreading in flat strands up to 1 mm. broad, which divide at short distances into a radiating fan of branches, one of which continues as the main strand, ultimately united by a thin film into a continuous sheet on which the basidia are developed. Hymenium almost continuous, forming a rather compact layer 40 micron thick; basidia at first lateral, then clustered, on short erect hyphae, pyriform, or obconic, or narrow-oval, 8-12 x 4-6 micron, four-spored; sterigmata short, cylindric, 2 micron long; spores hyaline, oval and inequilateral, or broadly cymbyform 4-6 x 2.5-4 micron. On leaves of coco-nut, New Guinea, March, 1924.

There is little to add to Bryce's description of this disease as occurring in New Guinea 1924.

It is, however, more widely spread than was indicated by him, and for example, is probably more serious in the areas of heavy rainfall, such as Gasmata and Bougainville Island, than in the districts he mentions.

Thread blight is widely spread over New Guinea, but is more in evidence under certain conditions such as in swampy low-lying spots. It was noticed by the author in certain plantations both in Bougainville and New Ireland last season as causing severe defoliation which often led to a whip sticking effect. The disease was more severe in protected valleys and pockets surrounded by hills where the air was particularly still and moist, e.g., near the foothills on the landward side of the plantations. Palms near the edges of swampy areas or close to heavy jungle were also noticeably more affected. One low-lying area surrounded by high trees and close to the two branches of a river showed severe thread blight. Other areas where palms were planted in pockets of low-lying ground surrounded by timber and swamp were very badly affected with both pestalozzia and thread blight, and many overhanging dead fronds were present. Where the outside timber was removed and cover crop became well established a couple of affected areas showed much improvement. Thread blight became serious on some plantations in New Guinea after severe *Promecotheca* attack.

Simmonds in 1923[66] reported on "Silver Film Disease", which, from the description given, was undoubtedly analogous with the thread blight described by Bryce. He described the disease as being due to a fungus having a white spreading external mycelium which travels along the midrib of the leaves and spreads out over the leaflets, which turn brown from the bases. The disease occurred in New Britain, the Solomon Islands and the New Hebrides, and is essentially a disease of wet and badly-drained areas. In wet seasons, however, it is apt to spread over the higher lands, causing the trees to turn brown and drop their young nuts. Draining and burning old leaves were recommended as the best treatment, though it was considered that in some places where the land is low-lying it would be wise to cut the trees right out. It appears that attention to cultural conditions, drainage, and not planting coco-nuts under unsuitable conditions would lead to less thread blight. The fact that some palms are less affected than others in a

badly diseased area indicates that there should be some inherent resistance to the disease which could be brought out by selection, e.g., by a method of close-breeding selected palms.

There is another form of thread blight present in New Guinea known as *Marasmius palmivorus,* the perfect stage of which in Malaya was suspected as a cause of bud-rot, but was proved only secondary in its effects.

The fungus strands are found growing over the upper surface of the leaf bases where they are closely addressed to the stem. Its mycelial threads are seen as whitish fan-shaped radiations on the surface of the leaf bases. This fungus, however, is not serious, as it is mainly saprophytic, growing profusely in the presence of abundant moisture. It does hasten the death of the tissues when some other disease is present and, on dead tissue, can usually be distinguished by the pink-coloured stalked and cap-shaped fruiting bodies. Under moist conditions, however, they are more whitish or brownish in colour and have very convoluted and up-turned edges.

STEM BLEEDING DISEASE.

This is Also Described as Stem-Rot by Nowell[46].

Stem bleeding disease (*Thielaviopsis ethacetica* now *T. paradoxa* or *Ceratostomella paradoxa*) was proclaimed a disease subject to the provision of "Plantation Diseases and Pests Ordinance of 1916"[38] which has been operating in this Territory and was described as follows:—

"This disease is revealed by the presence of a brown rusty coloured liquid which afterwards turns black, oozing out through cracks in the bark or stem of coco-nut palms. The disease does not become apparent until the liquid oozes out, but when this takes place the tissues are already decayed to a certain extent.

Approved remedial measures were: Excision of the affected part, taking care that the excision is carried to the limits of the diseased and discoloured tissues. The parts cut out to be burnt *in situ* and the wound burnt with a torch and afterwards covered with hot coal tar."

The association of *Thielaviopsis paradoxa* (*Ceratostomella paradoxa*=perfect stage) with lightning strike, bad drainage conditions and nut-fall has been indicated previously in this article. It is also known to attack palms and cause stem bleeding where fires or where grass knives or other agencies inflict wounds on the stem. It has been recorded by Ashby in Jamaica[6] that natural cracks an inch or more long tend to form on the trunks of palms when rain sets in following a dry period. This fungus infects these wounds and may penetrate deeply where neglected. In old and hardened palms affected with stem bleeding the rot is usually only present in small localized areas.

It has been seen by the author on palms in badly-drained areas. The outside lesions may be quite small but when cut open with a knife are seen to spread considerably beneath the skin. In advanced stages the tissue becomes black or yellowish black and the fibres of the trunk appear frayed and fluffy. In other cases large, diseased patches crack all over and red, gummy exudations occur where the cracks appear. Often removal of the tough outer skin reveals a patch of soaked and sodden tissue, which later becomes yellow or reddish in colour and is followed by browning or blackening as decay progresses. Garment[31] describes

Thielaviopsis spp., as causing stem bleeding of coco-nuts at Cicia, Fiji—he described the fungus and mentioned that the perfect stage of this fungus (pycnidial stage) was present.

Ashby[4] states that two clearly recognizable diseases of the central shoot which do not as a rule terminate in a rot of the bud occur in the West Indies. These are the Thielaviopsis leaf-rot and the little leaf disease (*see* under Frond Choke).

Thielaviopsis paradoxa is the cause of large, wedge-shaped spots with broad, dark margins which run across the folded segments of the young leaves in the

STEM BLEEDING PALM.—See blackened base also showing leaf droop.

shoot before they are pushed up into the light; as the leaves open out the midribs of the pinnae break at the diseased places and the terminal parts wither or tear away, giving the crown a ragged appearance. The fungus is invariably present in the rotten spots and sporulates freely in the tissue. The disease was epidemic in Jamaica for some years on young bearing trees from ten to fifteen years of age in a coastal belt of about 40 miles long having a high rainfall. Natural recovery

occurred but many cases were cured by cutting back the central shoot below the spotted region and applying a dry mixture of lime and sulphate of copper to the severed surface.

As the condition of stem bleeding is familiar to most planters here it is not necessary to describe the symptoms in detail. It is generally considered that *Thielaviopsis paradoxa* is not a strongly parasitic fungus, and hence is more liable to attack palms growing under unfavorable conditions or with poor vitality. General improvement of the cultural conditions is usually indicated where this disease is present. Cutting out diseased patches on palms situated over large areas is often not practicable but should be carried out where it is possible. Treatment of the diseased patches with Bordeaux paste, tar, &c., will not clear up the disease unless the general health of the palms is improved. The fungus is widely spread and the fact that continued burning off at the base of coco-nut palms provides easy entry for infection by *Thielaviopsis* should not be lost sight of, where such burning off is practised.

GREY BLIGHT—Pestalozzia Palmarum.

This was recorded here by German investigators as early as 1904. This leaf disease is well described in all standard text books and is familiar to planters in this Territory. It has been mentioned as causing rather serious damage under very wet conditions or where drainage conditions were poor or the vitality of the palms lowered by other causes such as soil exhaustion or insect attack. It is usually worst in densely planted young plantations especially in a very wet climate. It is often secondary and enters wounds made by Hispid beetles, but, under wet climatic conditions, it can become serious. It becomes very evident after *Promecotheca*.

Simmonds 1924[66–67] said that "Grey Blight" was a fungus disease starting in a small brownish spot which developed in concentric brown rings, giving the appearance of watered silk to the affected spot. In the Solomons where the disease was prevalent Messrs. Lever Bros., were stated to have found that burning all rubbish and smoking the trees was the best treatment. How smoking would effect a cure of a fungus disease would be difficult to explain.

It must be stressed that with both this fungus and *Helminthosporium spp.*, which is often associated with leaf blight here, the burning off of trash where the disease is severe, and improvement of cultural conditions, drainage or cultivation are the only practical means of control at present available.

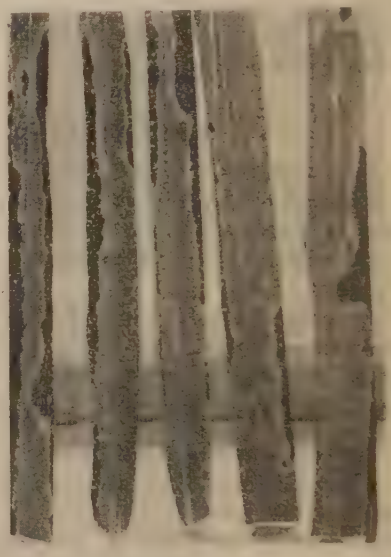
BACTERIAL LEAF BLIGHT.

A severe leaf disease which is prevalent in coco-nuts in New Britain, and is believed to be present elsewhere in New Guinea was identified recently by the author as being due to a bacterial pathogen. As far as known, this is the first record of a coco-nut disease of this nature from these islands. It was first noticed that a leaf disease was affecting palms on two plantations close to Rabaul, during the months of November and December, 1936. Mr. Moody, inspector and instructor, also stated that he had noticed the disease as being somewhat severe on various plantations here.

It was a significant feature that the leaves should show a severe die-back when the climatic conditions were more than usually wet, and further it was more prevalent on well-grown and otherwise healthy palms growing close to the foreshore. Its rather sudden seasonal appearance was noted by plantation owners who were inclined to ascribe the leaf die-back to strong, high winds. This bacterial disease is most liable to appear in the wet season, when it gives the plantation somewhat the same appearance as where drying off occurs after a severe drought.

The strong palms on the foreshore are more frequently affected than those in the back areas of the plantation, which indicates that the disease is not necessarily associated with soil exhaustion. The reason for the foreshores being most affected may be due to the fact that the atmosphere would be continuously humid, which could be expected to assist bacterial growth. The condition has been confused

LEAVES AFFECTED WITH BACTERIAL BLIGHT.



LEAVES AFFECTED WITH BACTERIAL BLIGHT.

with ordinary "tip-wither", but is distinguishable from the disease usually termed "tip-wither" here by several well defined symptoms, although in some cases the tips of the lower leaves may be worst affected by this disease.

The pinnules or leaflets may be attacked either at the base of the petiole or along its whole length; also diseased and healthy leaflets may appear in alternate areas on the petiole or main leaf-stalk. Often dark coloured lesions are seen on the back of the midribs of the affected pinnules (leaflets), and more rarely rather larger affected areas. It is, however, mainly a leaf-disease which at first attacks the lower leaves and gradually progresses upwards, being largely confined to the pinnules. This leaf disease should not be confused with *Pestalozzia palmarum*, as will be seen by the description given below, nevertheless *Pestalozzia* is seen often on the dead tissues which were primarly killed by the more severe bacterial infection. The lesions of the bacterial leaf blight are usually much larger and more irregular in outline than those caused by *Pestalozzia*, while the

dark spotting, which indicates the presence of the perfect stage of the latter disease, is absent except in the case of secondary infection. The first sign of the disease on the leaflets is the presence of small, dark-brown, discoloured, isolated areas with very distinct halos surrounding them. Their first appearance is usually seen near the base of the leaflets. As the size of the lesion increases the whole central area dies but remains intact, becoming light brown and shiny on the lower surface, but a rather slatey-grey colour on the upper surface. The lesions or diseased areas progress along the blade and the leaflet until they join up and the whole leaflet may become affected, though in most cases narrow, green, irregular shaped areas persist at the edges of the leaf.

The appearance of the affected area when the disease is well advanced is most distinctive, and hence is readily discernible by eye (macroscopic) characters. The edges of the diseased areas are usually raised, especially on the under surface, and appear yellowish in colour, though changing gradually to a lighter green, water-soaked zone which, while fresh, is quite transparent when held up to the sun, changing also to a yellowish green when dry. When this zone at the edge of the affected area, which indicates where the disease is progressing into healthy tissue, is examined by reflected light, a shiny, thin plate of almost transparent, whitish, bacterial exudate is seen. When this shining exudate is examined under the microscope it is found to be simply teeming with bacteria, which is also characteristic of most bacterial diseases found in the temperate zone. Another very distinguishing characteristic is the striped dark brown appearance where much darker areas are seen to persist close to the parallel and smaller leaf veins. Inside the dry areas of other lesions may be seen smaller and very irregular, almost black, streaked areas, often pitted and raised, which represent where the last patches of tissue were affected or where two or more diseased areas have coalesced. In even the most advanced stages the diseased areas become mottled in appearance and gradually become more pitted and stand out prominently, especially near the edges of the diseased zone.

The original entry of the disease may be through injuries from *Promecotheca* and other leaf-eating insects, as was seen frequently where the diseased lesions surrounded insect-bitten areas. It was seen also associated with scale attack. The whipping effects of strong winds, plus a moist atmosphere, may provide favorable conditions for infection, and also for the spread of the disease in the direction of the wind. It seems, however, that the disease most frequently appears where no apparent previous injury is present. The attack of old diseased leaflets by the *Fusarium spp.* of fungus and moulds of various kinds often causes the upper surface of these larger areas to become dirty and mouldy in appearance, while the lower surface remains smooth and clean.

As to remedial measures, cutting off and burning diseased leaves or any fallen trash may assist to control the disease, but it is doubtful whether such operations would be effective and economical. It is not likely to be so prevalent in the dry season, and in fact may only prove serious after a dry season where more rain than usual is experienced, such as happened recently.

The specific nature of the organism responsible for the disease and its cultural characteristics have not yet been determined, and work is proceeding in this direction. More data is required before any suggestion as to the desirability of control could be given.

LEAF DROOP.

Described by Petch.[84]

This condition as described by Petch[84] refers to a drooping of the lower fronds of the palm. In well marked cases up to one dozen leaves bend down while still green and form a curtain around the stem, though sometimes only two or three are affected. Ultimately these drooping leaves die and turn brown; as a rule they do not immediately drop off, but remain hanging down parallel to the stem. The leaves on the upper half of the crown remain in their normal position and thus the crown appears divided into two distinct parts. If one of

LEAF DROOP ON RECOVERED HEAD DROOP PALM. (See twisted palm.)

LEAF DROOP ON A PALM ALSO SUFFERING FROM SOIL EXHAUSTION.

the affected leaves is cut while still green it will be found that the only part diseased or decayed is the swollen base of the leaf stalk where the tissue turns soft and dark brown or blackish. The *Phytopthora* which causes the fall of nuts has been found on the diseased leaf bases and there is no doubt that the leaf-droop and the nut-fall are only two different manifestations of the effect of the same fungus.

Palms with the same outward appearance have been seen in this Territory and the condition is not rare, but has not been serious as far as is known. Probably there has been some other primary cause for the effects shown here, but this has not been investigated so far, and *Phytopthora* may be present. Marr, Inspector and Instructor, stated that he has se en this condition which he named " premature frond fall " (on Kar Kar Island) and it was noticed that the lower spathes and nuts fell away after the leaves had withered.

Leaf-droop has been observed rather commonly on the mainland. The leaves which hung down were bunched and dead or nearly so, while the upper fronds often appeared quite healthy. Marasmius thread blight was quite common at the base of these fronds and appeared to have progressed much more than on the normal fronds. The bases were noticeably very rotten and often became infested with white ants. The leaf scars appeared close together while the dead spathes often remained attached to the palms. In one plantation where it was particularly bad the palms were old and the soils shallow and of coral derivation. Nut-fall under these conditions was relatively prevalent.

Leaf-droop in New Guinea appears to be associated with poor soil conditions and it was noticeable that palms which were not affected with leaf-droop showed nut-fall in the same plantation.

LEAF BREAK DISEASE.

C. H. Gadd[32] described leaf break disease of coco-nuts in Ceylon, which was also previously investigated by Richards in Malaya[53] and Stockdale[75] and Nowell[46] in the West Indies.

From a reproduction of the photograph and the description given it will be readily seen that this condition or disease is not uncommon in New Guinea. The author has seen it particularly in closely planted native groves, though it is present to a lesser extent on the European plantations here where unfavorable cultural conditions exist.

Affected trees are very conspicuous owing to the presence of leaves broken about the middle, while the withered terminal (distal) end hangs vertically downwards. The disease commonly starts at a terminal leaflet of one of the older leaves and the leaflet withers and turns brown. At the base of the dead leaflet on the midrib is a dark-brown, discoloured area, which extends along the petiole as the disease advances and later turns black. The disease advances rapidly, and often pairs of leaflets are killed in succession as the discoloured area progresses along the midrib. Eventually the leaf breaks, usually about the middle, sometimes nearer the base, and the withered end hangs downward. The withering of the leaflets is due to stoppage of the water supply, when the fungus kills the tissue. The breaking of the leaf is due to the weight of the diseased portions, for only the horizontal or upwardly inclined leaves break. Old leaves which are hanging downwards do not usually break when attacked.

The fungus recorded by all the investigators mentioned as responsible for this condition is *" Diplodia "* or *" Botryo-diplodia "*, a fungus which has been recorded several times on coco-nuts in New Guinea, and also recorded by Dr. Noble[67] on young nuts with a ring disease. In some cases the fruiting bodies or fructifications of *Botryo-diplodia* are often seen as small black pustules on the

diseased leaf stalks and leaflets which break through the epidermis, liberating large numbers of black two-celled spores. This fungus has its powers of parasitism limited in most cases to the invasion of tissues (except fruit) with less than normal vigour, i.e., weakly parasitic.

LEAF BREAK DISEASE.

It is believed that *Botryo-diplodia,* the organism causing leaf-break, usually attacks palms of low vitality and those which have been infected by other diseases. It is, for example, often associated with *Pestalozzia,* and entry of the fungus is usually obtained through wounds and dead tissues.

Remedial Measures.

The diseased leaves should be cut off and burnt, the leaf stalks being cut at least 6 inches behind the diseased tissue. If the tree is weak it may pay to paint cut surfaces with a fungicidal paste. The leaves to be destroyed should be burnt where cut and not carried through the plantation.

As trees of low vitality are most liable to attack, proper attention to drainage, cultural methods and manuring should be given to increase the vigour of the palms. Stockdale[78] said "that leaf-break was most common in plantations in Ceylon where the agricultural conditions were unsatisfactory. He quoted some evidence that it may be a 'deficiency disease' and hence would be less common on well-cultivated areas".

TIP-WITHER.

Bryce[18] and Simmonds,[66] 1924, have both mentioned this disease. tip-wither, in coco-nuts in New Guinea and the following short description was given by the latter:—

"Throughout New Britain and the New Guinea coast a disease known as 'tip-wither,' causing the ends of the leaves to brown and giving a yellowish appearance to the whole plantations, was prevalent."

Bryce[18] mentioned the presence of the condition "withering of leaflets" on a plantation in the Namatanai District, New Ireland, and stated that no causative organism for this disease was found. It is probably due to poor soil conditions or to insect attack. It is not clear from the description given what disease is actually meant and whether this disease is synonymous with leaf break. It apparently refers to the tip of the frond dying which may be due to diverse causes. It appears fairly certain that fungi like *Botryo-diplodia* and *Fusarium spp.* are associated with tip-wither, but these do not appear to be a primary cause of the condition. This disease is often associated with soil deficiency. On young palms the lower leaves are often seen to die from the tips backwards towards the base and this is associated with pestalozzia and other fungi. Usually this can be attributed to a more or less normal shedding of the leaves. In times of drought a kind of tip wither of the fronds can be noticed, thus this condition can be regarded as a symptom rather than a specific disease.

An occurrence of tip-wither associated with some "leaf-break" was investigated recently on one plantation in New Britain. The main disease present, however, was "chlorosis," due to soil deficiency, which stunted the palms and led to shortening and reduction of the number of leaves. The soil horizon here was worth noting, as it was composed largely of volcanic ash and pumice. It was seen that it was composed of several distinct layers indicating different periods of upheaval. Two of the layers, at some little depth, showed a greater proportion of pumice than the others, while one layer was inclined to be fine grained and more clayey. This may have provided a block to root growth where the young palms were not looked after and *Imperata arundinacea* was allowed to grow.

The interesting discovery was that the tip-wither and "leaf-break" present in all cases showed the presence of a chlanydospore producing species of fusarium. At least three spore forms were seen under microscopic examination. It was also seen that the fungus caused a very distinct yellowing of the inner tissues, which later turned brown. Another important feature was that the large brownish coloured lesions, particularly on the main petiole, and less frequently on the diseased leaflets, showed irregular coloured raised areas. On closer examination, by eye, these were seen to be composed of numerous round, regularly-shaped, distinctly-red, fruiting bodies. This was undoubtedly the "nectria" stage or perfect fruiting stage of the species of fusarium present. This fungus was found constantly at the junction of the diseased and healthy tissue, but no indication of the *Botryo-diplodia* fungus which has been said to cause the disease was seen in any of these examinations. A similar species of fusarium has been met with in material derived from both the mainland of New Guinea and New Ireland. In various stages it strongly resembles *Fusarium chlamydosporum*, described by Reinking and Wollenweber in their article on tropical fusaria[57].

Microscopic slides of the fungus were made for later despatch to the Imperial Mycological Institute for proper identification. In the author's opinion, the species of fusarium described is responsible for many of the conditions which have been usually attributed to *Botryo-diplodia* here. It was interesting to see that one spore-form of the fungus was very like *Botryo-diplodia* in shape and size and would easily lead to confusion; more investigation is needed to clear up this point.

Apparently, the *Fusarium spp.*, present in coco-nuts in New Guinea, only attacks the palm when its vitality is lowered by some outside cause, such as soil deficiency. (*See* also technical discussion on the physiological disease recorded from New Ireland.)

"SILVER LEAF DISEASE."

This condition must not be confused with the "silver film disease" described by Simmonds[66] which, from the description given, appeared to be a "thread-blight". The appearance of "silver leaf disease" is not unlike that found in the "silver leaf disease" of peaches and plums which occurs under unfavorable environmental conditions in Australia and which is due to a definite fungus. The author has seen this condition only in a few instances in New Guinea, but, as far as is known, this is the first published record of this disease which causes a silvering of the leaf surface, and does not appear to be deep-seated. On one occasion it was seen on palms in New Ireland associated with "head droop" (*see* description of that disease). It has also been seen on palms showing nut-fall on the mainland and, in some instances, on sickly palms in New Britain. Planters have recalled the condition when it was described to them, hence it is thought to be fairly widespread in this country. The disease is most readily recognized by the shining, greyish or silvery sheen present on the affected leaves and which is quite distinct from the normal, bright green colour of coco-nut leaves. The leaflets do not appear to die back, where the condition is present, and it is seldom associated with any browning or development of distinct lesions.

The cause of the disease has not been established yet, but, on one slide, a surface fungus growth, showing a very fine mycelium and very small rounded pycnidia, was seen. This has not been identified. Some unidentified thrips and scale insects were also present. The disease is not believed to be serious, but there is the possibility that it may be associated with some weakness of the palm, or else indicate some unfavorable symptoms. It may be due to a surface mildew fungus, or thrip-injury, but further investigation is necessary before the cause can be definitely established.

DISCUSSION.

It appears from the investigations already made that this country is, as yet, free from some of the most serious fungal, bacterial and nematode diseases of coco-nuts which cause serious losses in the coco-nut industry in other parts of the world.

Epidemic bud-rot, although previously suspected, is not present in New Guinea.

Red ring disease of coco-nuts due to *patho-aphelenchus cocophilus*, a nematode, is also not present here.

Bronze leaf wilt of coco-nuts which is a serious disease in the West Indies is apparently not of any importance in this Territory.

Serious *root diseases* have not been recorded here and *nut-fall* has been only sporadic in its incidence.

The attention of the planting community is drawn to the discussion on "deficiency diseases" which are of great and increasing importance in this Territory. This is more especially so as the reduced vigour of the palm accompanying soil-exhaustion lays it open to serious fungus attack by normally weakly parasitic organisms, which are incapable of causing serious damage to healthy palms.

SUMMARY.

An account of the diseases due to fungi, physiological causes and soil deficiencies so far recorded in New Guinea is presented.

It appears that chlorotic deficiency diseases of coco-nut palms which are associated with soil deficiency or soil exhaustion are very important in this country, and will become progressively worse as plantations grow older. Affected palms appear a sickly yellowish green in colour and the fronds gradually become shorter and fewer until eventually the few remaining fronds present a feathery, unhealthy appearance. This often leads to tapering stem and general collapse of the cabbage.

Root diseases do not cause much concern to New Guinea planters. No serious occurrences have been reported and where suspected have usually been associated with low-lying heavy soils or where soil deficiency was in evidence.

Root-rotting is unlikely to cause trouble where the vigour and health of the palms is maintained.

There is no authentic record of true infectious or epidemic *bud rot* occurring in New Guinea. The types of false bud-rot here fall roughly into three categories:—

1. *False bud-rot,* due to lightning strike or fires.
2. *Tapering stem and collapse of the bud,* primarily due to soil exhaustion.
3. *Sporadic bud-rot,* usually secondary to injuries of various kinds.

So far "*nut-fall*" has not been widely prevalent in New Guinea. Severe incidences have been very localized and only reported at intervals from plantations in this Territory. The causes of nut-fall are discussed, and it appears that soil conditions, in some cases associated with insects such as spathe borer, have been the chief causal agencies here.

"*Head droop*"—A suspected virus or physiological disease is a most baffling condition in coco-nut palms, which is common in parts of New Guinea. So far as is known this is the first published description of this disease and possible causes and need for further investigation are stressed.

"*Frond choke,*" which is believed to be generally hereditary but may be brought about by environmental conditions, and another obscure physiological disease from New Ireland are described.

Stem bleeding disease, thread blight, grey leaf blight, a bacterial leaf blight, leaf break, leaf droop, tip wither and *ring disease* of immature nuts are other diseases which are described and remedies suggested where possible.

It is stressed that where the vigour of coco-nut palms is lowered by any cause whatsoever, such as drought, unsuitable soil conditions, soil exhaustion or insect attack, the palms are rendered liable to serious attack from fungi which are normally only weakly parasitic.

ADDENDUM.

(Of technical interest mainly.)

LIST OF COCO-NUT DISEASES RECORDED IN NEW GUINEA TO THE PRESENT TIME.

ROOT ROTS:

Fomes Lignosus (probably East Indies type) = *Rigidoporus microporus.*
Fomes lucidus = *Ganoderma lucidum.*
Brown Root-rot = *Fomes noxious.*
Rhizoctonia bataticola = *Macrophomia phaseoli*—So far seen only on other plants here; recorded on coco-nuts in other countries.

STEM DISEASES:

Stem Bleeding Thielaviopsis (*Ceratostomella paradoxa*)—Often associated with Lightning Strike.
Marasmius palmivorus, Polyporus spp.

BUD ROTS:

Epidemic Bud-rot (*Phytopthora faberi*)—Suspected and described by Bryce and others: in view of recent findings doubtful whether this is present.
False Bud-rot—Primarily due to lightning strike, or, in some cases, fires.
Sporadic Bud-rot—Mainly due to injuries. Numerous cases recorded from all parts of New Guinea.
Tapering Stem (*see* below)—Leading to collapse of the cabbage.

LEAF DISEASES:

Thread Blight—Corticium penicillatum.
Grey Blight—Pestalozzia palmarum.
Leaf Spotting—Due to *Helminthosporium spp.* (probably *H.-incurvatum* or an *Acrothecium*).
Sooty Mould—Capnodium or *Meliola spp*; *Anthostoma Cocois* (recorded by Rechinger).
Silver-Leaf—Cause not known, thrips may assist, fungus present.
Leaf-Droop—Soil deficiency and various fungi.
Leaf-Break—Soil deficiency. *Botryo-diplodia, Fusaria, &c.*
Tip Wither—Probably similar to above; *Nectria* stage present.
Bitten Leaf—Thielaviopsis spp.
Leaf Blight—Bacterial.

DISEASES OF THE NUT:

Ring Disease—Botryo-Diplodia spp. (identified by R. J. Noble).
Nut-fall—Associated with environmental and soil conditions, insects and various fungi.
Leathery Copra—Associated with soil deficiency.

PHYSIOLOGICAL DISORDERS:

Chlorosis and Die-Back—Due to soil exhaustion. Often leads to collapse of the cabbage.
Frond Choke—Probably also hereditary. Believed that it may be due to soil disorders.
Drought Wilt—Common in times of drought. Some forms of Tip Wither may belong to this category.
Obscure physiological disease in New Ireland, causing wilting of central fronds of young palms.

SUSPECTED VIRUS DISEASE:

Head Droop (also known as Cabbage Droop, Corkscrew, or Cabbaging).

GENITAL ABNORMALITIES (POSSIBLE MUTATIONS AND STRAIN EFFECT):

Yellowing of the palms—May be genetical, as well as due to disease.
Female palms—Male flowers suppressed; nuts often without embryos or with very little copra.
Particular palms produce soft copra, which will not cure; might be hereditary in some cases.
Branching and twin palms.
Leaf bases remaining attached to the palms either on the whole or portion of the trunk.

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